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16. ABSTRACT

Laboratory technique for testing materials in cement treated base construction is not yet nationally standardized. However, certain procedures, based on experience and information available to date, have been adopted by the Materials and Research Department and are detailed herewith for the guidance of the Resident Engineer and assistants in charge of such work.

The instructions for each test, or procedure, have been bound in individual booklets, which, for convenience of distribution are assembled herewith in one folder as follows:

A. Table of Quantities of Materials
B. Determination of Dry Weight per Unit Volume
C. Instructions for Fabrication of Test Specimens
D. Determination of Optimum Moisture Content
E. Chart for the Rapid Calculation of Relative Humidity

The sketches and charts have been duplicated in booklets C and D. This arrangement permits the separate use of each booklet as an integral set of instructions.

The information contained herein is intended primarily for field use and no attempt has been made to describe all operations now being followed in the Central Laboratory.

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STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF HIGHWAYS

Materials and Research Department

INSTRUCTIONS FOR CONTROL TESTS
ON
CEMENT TREATED BASE PROJECTS

Revised - March, 1942

STATE OF CALIFORNIA

Department of Public Works Division of Highways

Materials and Research Department

FOREWORD

Laboratory technique for testing materials in cement treated base construction is not yet nationally standardized. However, certain procedures, based on experience and information available to date, have been adopted by the Materials and Research Department and are detailed herewith for the guidance of the Resident Engineer and assistants in charge of such work.

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E. Chart for the Rapid Calculation of Relative Humidity

The sketches and charts have been duplicated in booklets C and D. This arrangement permits the separate use of each booklet as an integral set of instructions.

The information contained herein is intended primarily for field use and no attempt has been made to describe all operations now being followed in the Central Laboratory.

While the instructions for determining optimum moisture are included for use, if necessary, it is recommended that this value be determined by the Central Laboratory whenever possible.

STATE OF CALIFORNIA

DEPARTMENT OF PUBLIC WORKS DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

TABLE OF QUANTITIES OF MATERIALS REQUIRED FOR THE CONSTRUCTION OF CEMENT TREATED BASES

March, 1942

QUANTITIES OF MATERIALS REQUIRED FOR THE CONSTRUCTION OF CEMENT TREATED BASES

The attached table of quantities has been prepared in order to facilitate computation of the quantities of cement and of soil or aggregate required for the construction of cement treated highway base courses.

The quantities shown in the table are based on a unit volume of one cubic yard of treated and compacted base.

The extreme left hand column shows unit compacted dry weights of the treated material expressed in pounds per cubic foot, ranging from 90 to 145, while the adjacent column shows the total compacted dry weight per cubic yard.

The remaining columns show the weights of untreated soil and the quantities of cement (in pounds and in sacks) for each compacted unit weight of the mixture with cement contents ranging from 3% to 10% of the dry weight of the untreated aggregate.

TABLE OF UNIT QUANTITIES
FOR
CALCULATION OF MATERIAL REQUIREMENTS IN SOIL-CEMENT CONSTRUCTION

Quantities of Untreated Soil or Aggregates and of Portland Cement for 1 Cu. Yd. of Compacted Base

Compacted Dry Weight of Cement Treated Base in Lbs. per		3% *			4% *			5% *			6% *		
		Weight Agg.	Cement		Weight Agg.	Cement		Weight Agg.	Cement		Weight Agg.	Cement	
Cu. Ft.	Cu. Yd.	Lbs.	Lbs.	Sacks	Lbs.	Lbs.	Sacks	Lbs.	Lbs.	Sacks	Lbs.	Lbs.	Sacks
90	2430	2359	71	0.76	2337	93	0.99	2314	116	1.23	2292	138	1.47
91	2457	2385	72	0.77	2363	94	1.00	2340	117	1.24	2318	139	1.48
92	2484	2412	72	0.77	2388	96	1.02	2366	118	1.26	2343	141	1.50
93	2511	2438	73	0.78	2414	97	1.03	2391	120	1.28	2369	142	1.51
94	2538	2464	74	0.79	2440	98	1.04	2417	121	1.29	2394	144	1.53
95	2565	2490	75	0.80	2466	99	1.05	2443	122	1.30	2420	145	1.54
96	2592	2516	76	0.81	2492	100	1.06	2469	123	1.31	2445	147	1.56
97	2619	2543	76	0.81	2518	101	1.07	2494	125	1.33	2471	148	1.57
98	2646	2569	77	0.82	2544	102	1.09	2520	126	1.34	2496	150	1.60
99	2673	2595	78	0.83	2570	103	1.10	2546	127	1.35	2522	151	1.61
100	2700	2621	79	0.84	2596	104	1.11	2571	129	1.37	2547	153	1.63
101	2727	2646	79	0.84	2622	105	1.12	2597	130	1.38	2573	154	1.64
102	2754	2674	80	0.85	2648	106	1.13	2623	131	1.39	2598	156	1.66
103	2781	2700	81	0.86	2674	107	1.14	2649	132	1.40	2624	157	1.67
104	2808	2726	82	0.87	2700	108	1.15	2674	134	1.43	2649	159	1.69
105	2835	2752	83	0.88	2726	109	1.16	2700	135	1.44	2675	160	1.70
106	2862	2779	83	0.88	2752	110	1.17	2726	136	1.45	2700	162	1.72
107	2889	2805	84	0.89	2778	111	1.18	2751	138	1.47	2725	164	1.74
108	2916	2831	85	0.90	2804	112	1.19	2777	139	1.48	2751	165	1.76
109	2943	2857	86	0.91	2830	113	1.20	2803	140	1.49	2776	167	1.78
110	2970	2883	87	0.93	2856	114	1.21	2829	141	1.50	2802	168	1.79
111	2997	2910	87	0.93	2882	115	1.22	2854	143	1.52	2827	170	1.81
112	3024	2936	88	0.94	2908	116	1.23	2880	144	1.53	2853	171	1.82
113	3051	2962	89	0.95	2934	117	1.24	2906	145	1.54	2878	173	1.84
114	3078	2988	90	0.96	2960	118	1.26	2931	147	1.56	2904	174	1.85
115	3105	3015	90	0.96	2986	119	1.27	2957	148	1.57	2929	176	1.87
116	3132	3041	91	0.97	3012	120	1.28	2983	149	1.59	2955	177	1.88
117	3159	3067	92	0.98	3038	121	1.29	3009	150	1.60	2980	179	1.90
118	3186	3093	93	0.99	3063	123	1.31	3034	152	1.62	3006	180	1.91
119	3213	3119	94	1.00	3089	124	1.32	3060	153	1.63	3031	182	1.94
120	3240	3146	94	1.00	3115	125	1.33	3086	154	1.64	3057	183	1.95
121	3267	3172	95	1.01	3141	126	1.34	3111	156	1.66	3082	185	1.97
122	3294	3198	96	1.02	3167	127	1.35	3137	157	1.67	3108	186	1.98
123	3321	3224	97	1.03	3193	128	1.36	3163	158	1.68	3133	188	2.00
124	3348	3250	98	1.04	3219	129	1.37	3189	159	1.69	3159	189	2.01
125	3375	3277	98	1.04	3245	130	1.38	3214	161	1.71	3184	191	2.03
126	3402	3303	99	1.05	3271	131	1.39	3240	162	1.72	3209	193	2.05
127	3429	3329	100	1.06	3297	132	1.40	3266	163	1.73	3235	194	2.06
128	3456	3355	101	1.07	3323	133	1.41	3291	165	1.76	3260	196	2.08
129	3483	3382	101	1.07	3349	134	1.43	3317	166	1.77	3286	197	2.10
130	3510	3408	102	1.08	3375	135	1.44	3343	167	1.78	3311	199	2.12
131	3537	3434	103	1.09	3401	136	1.45	3369	168	1.79	3337	200	2.13
132	3564	3460	104	1.10	3427	137	1.46	3394	170	1.81	3362	202	2.15
133	3591	3486	105	1.12	3453	138	1.47	3420	171	1.82	3388	203	2.16
134	3618	3513	105	1.12	3479	139	1.48	3446	172	1.83	3413	205	2.18
135	3645	3539	106	1.13	3505	140	1.49	3471	174	1.85	3439	206	2.19
136	3672	3565	107	1.14	3531	141	1.50	3497	175	1.86	3464	208	2.21
137	3699	3591	108	1.15	3557	142	1.51	3523	176	1.87	3490	209	2.22
138	3726	3617	109	1.16	3583	143	1.52	3549	177	1.88	3515	211	2.24
139	3753	3644	109	1.16	3609	144	1.53	3574	179	1.90	3541	212	2.26
140	3780	3670	110	1.17	3635	145	1.54	3600	180	1.91	3566	214	2.28
141	3807	3696	111	1.18	3661	146	1.55	3626	181	1.93	3592	215	2.29
142	3834	3722	112	1.19	3687	147	1.56	3651	183	1.95	3617	217	2.31
143	3861	3749	112	1.19	3713	148	1.57	3677	184	1.96	3642	219	2.33
144	3888	3775	113	1.20	3738	150	1.60	3703	185	1.97	3668	220	2.34
145	3915	3801	114	1.21	3764	151	1.61	3729	186	1.98	3693	222	2.36

Compacted Dry Weight of Cement Treated Base in Lbs. per		7% *			8% *			9% *			10% *		
		Weight Agg.	Cement		Weight Agg.	Cement		Weight Agg.	Cement		Weight Agg.	Cement	
Cu. Ft.	Cu. Yd.	Lbs.	Lbs.	Sacks	Lbs.	Lbs.	Sacks	Lbs.	Lbs.	Sacks	Lbs.	Lbs.	Sacks
90	2430	2271	159	1.69	2250	180	1.91	2229	201	2.14	2209	221	2.35
91	2457	2296	161	1.71	2275	182	1.94	2254	203	2.16	2234	223	2.37
92	2484	2321	163	1.73	2300	184	1.96	2279	205	2.18	2258	226	2.40
93	2511	2347	164	1.74	2325	186	1.98	2304	207	2.20	2283	228	2.43
94	2538	2372	166	1.77	2350	188	2.00	2328	210	2.23	2307	231	2.46
95	2565	2397	168	1.79	2375	190	2.02	2353	212	2.26	2332	233	2.48
96	2592	2422	170	1.81	2400	192	2.04	2378	214	2.28	2356	236	2.51
97	2619	2448	171	1.82	2425	194	2.06	2403	216	2.30	2381	238	2.53
98	2646	2473	173	1.84	2450	196	2.09	2428	218	2.32	2405	241	2.56
99	2673	2498	175	1.86	2475	198	2.11	2452	221	2.35	2430	243	2.59
100	2700	2523	177	1.88	2500	200	2.13	2477	223	2.37	2455	245	2.61
101	2727	2549	178	1.89	2525	202	2.15	2502	225	2.39	2479	248	2.64
102	2754	2574	180	1.91	2550	204	2.17	2527	227	2.41	2504	250	2.66
103	2781	2599	182	1.93	2575	206	2.19	2551	230	2.45	2528	253	2.69
104	2808	2624	184	1.95	2600	208	2.21	2576	232	2.47	2553	255	2.71
105	2835	2650	185	1.97	2625	210	2.23	2601	234	2.49	2577	258	2.74
106	2862	2675	187	1.99	2650	212	2.26	2626	236	2.51	2602	260	2.77
107	2889	2700	189	2.01	2675	214	2.28	2650	239	2.54	2626	263	2.80
108	2916	2725	191	2.03	2700	216	2.30	2675	241	2.56	2651	265	2.82
109	2943	2250	193	2.05	2725	218	2.32	2700	243	2.59	2675	268	2.85
110	2970	2776	194	2.07	2750	220	2.34	2725	245	2.61	2700	270	2.87
111	2997	2801	196	2.09	2775	222	2.36	2750	247	2.63	2725	272	2.90
112	3024	2826	198	2.11	2800	224	2.38	2774	250	2.66	2749	275	2.93
113	3051	2851	200	2.13	2825	226	2.40	2799	252	2.68	2774	277	2.95
114	3078	2877	201	2.14	2850	228	2.43	2824	254	2.70	2798	280	2.98
115	3105	2902	203	2.16	2875	230	2.45	2849	256	2.73	2823	282	3.00
116	3132	2927	205	2.18	2900	232	2.47	2873	259	2.76	2847	285	3.03
117	3159	2952	207	2.20	2925	234	2.49	2898	261	2.78	2872	287	3.05
118	3186	2978	208	2.21	2950	236	2.51	2923	263	2.80	2896	290	3.08
119	3213	3003	210	2.23	2975	238	2.53	2948	265	2.82	2921	292	3.11
120	3240	3028	212	2.25	3000	240	2.55	2972	268	2.85	2945	295	3.14
121	3267	3053	214	2.27	3025	242	2.57	2997	270	2.87	2970	297	3.16
122	3294	3079	215	2.29	3050	244	2.60	3022	272	2.89	2995	299	3.18
123	3321	3104	217	2.31	3075	246	2.62	3047	274	2.91	3019	302	3.21
124	3348	3129	219	2.33	3100	248	2.64	3072	276	2.94	3044	304	3.23
125	3375	3154	221	2.35	3125	250	2.66	3096	279	2.97	3068	307	3.26
126	3402	3179	223	2.37	3150	252	2.68	3121	281	2.99	3093	309	3.29
127	3429	3205	224	2.38	3175	254	2.70	3146	283	3.01	3117	312	3.32
128	3456	3230	226	2.40	3200	256	2.72	3171	285	3.03	3142	314	3.34
129	3483	3255	228	2.42	3225	258	2.74	3195	288	3.06	3166	317	3.37
130	3510	3280	230	2.44	3250	260	2.77	3220	290	3.09	3191	319	3.39
131	3537	3306	231	2.46	3275	262	2.79	3245	292	3.11	3215	322	3.42
132	3564	3331	233	2.48	3300	264	2.81	3270	294	3.13	3240	324	3.45
133	3591	3356	235	2.50	3325	266	2.83	3294	297	3.16	3265	326	3.47
134	3618	3381	237	2.52	3350	268	2.85	3319	299	3.18	3289	329	3.50
135	3645	3407	238	2.53	3375	270	2.87	3344	301	3.20	3314	331	3.52
136	3672	3432	240	2.55	3400	272	2.89	3369	303	3.22	3338	334	3.55
137	3699	3457	242	2.57	3425	274	2.91	3394	305	3.24	3363	336	3.57
138	3726	3482	244	2.59	3450	276	2.94	3418	308	3.28	3387	339	3.60
139	3753	3507	246	2.61	3475	278	2.96	3443	310	3.30	3412	341	3.63
140	3780	3533	247	2.63	3500	280	2.98	3468	312	3.32	3436	344	3.66
141	3807	3558	249	2.65	3525	282	3.00	3493	314	3.34	3461	346	3.68
142	3834	3583	251	2.67	3550	284	3.02	3517	317	3.37	3485	349	3.71
143	3861	3608	253	2.69	3575	286	3.04	3542	319	3.39	3510	351	3.73
144	3888	3634	254	2.70	3600	288	3.06	3567	321	3.41	3535	353	3.76
145	3915	3659	256	2.72	3625	290	3.09	3592	323	3.44	3559	356	3.79

* Percentages shown are for cement content based on the dry weight of the untreated soil or aggregate.

STATE OF CALIFORNIA

DEPARTMENT OF PUBLIC WORKS DIVISION OF HIGHWAYS

MATERIALS AND RESEARCH DEPARTMENT

INSTRUCTIONS

FOR THE

DETERMINATION OF THE DRY WEIGHT

PER UNIT VOLUME OF A

COMPACTED ROADBED OR A NATURAL SOIL

BY SAND VOLUME METHOD

March, 1942

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT

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BY SAND VOLUME METHOD

March, 1942

STATE OF CALIFORNIA
Department of Public Works Division of Highways
Materials and Research Department

INSTRUCTIONS FOR THE DETERMINATION OF THE DRY WEIGHT PER UNIT VOLUME OF A COMPACTED ROADBED OR A NATURAL SOIL

March, 1942

INTRODUCTION

There are frequent instances where it is necessary to measure accurately the volume of shallow and irregularly shaped holes in order to determine the unit weight of natural soils or the compacted dry weight per unit volume of material placed in a fill or roadbed. This is especially true where gravel or coarse particles of rock prevent the taking of undisturbed samples by mechanical means.

In the construction of cement treated bases, the degree of compaction is such an important factor in controlling the strength and quality of the finished product that frequent and accurate determination of the relative compaction is a very essential part of the construction supervision.

The equipment and the operating procedure described on the following pages was developed to facilitate the rapid and accurate determination of the unit compacted weight of cement treated bases but it is equally well adapted to the measurement of the volume of holes of reasonable depth and of not more than 10 inch diameter in fills, natural soil, rock, etc.

Sand (the weight per unit volume of which is known) has been used for volume determinations with varying degrees of success over a period of years. If the sand grains are of approximately the same size, and are clean and well rounded, excellent results can be obtained, provided absolute uniformity of operation is maintained at all times. The major difficulties have been encountered in securing a constant rate of flow of the sand into the hole and in leveling off the top of the sand to conform to the surface of the ground without causing partial settlement of the sand in the hole, or else loss of some of the excess sand.

In order to provide a uniform rate of flow of sand into the hole and to eliminate the difficulties involved in leveling off the surface of the sand, the equipment illustrated in the attached Sketch 3 has been developed by the Materials and Research Department. Somewhat similar equipment, involving the use of an inverted cone attached to a Mason jar, or other container, and controlling the flow of sand by means of a stopcock, has been in use in various localities for some time. The equipment herein described permits the use of larger sample holes, and is sturdier and more convenient for field use than is the case when glass jars are used.

EQUIPMENT

1 - Sand Volume Apparatus as shown in Sketch 3, consisting of:
    - a - Measuring Cone (Volume = 1/6 cu. ft.)
    - b - Overflow Vessel
    - c - Regulating Funnel
    - d - Auxiliary Ring

1 - Volume Measure (Volume = 1/6 cu. ft.) for use in obtaining unit weight of standard sand. (Also shown on Sketch 3)

1 - Balance with a capacity of 5,000 to 20,000 gms., complete with weights. (Balance sensitivity 0.02%, or better)

1 - Oven or hot plate for drying moisture samples.

1 - Set of digging and cleaning tools, including chisels, spatula, scoops, dippers, brushes, etc.

1 - Special carrying case for the Sand Volume Apparatus and miscellaneous tools.

1 - Carrying case for the Volume Measure.

1 - Toothed Hand Drill or Cutter. (Optional) (Advantageous for fine soils but not effective in the presence of coarse rock.)

A supply of standardized sand, containers, etc.

OPERATING PROCEDURE

The location chosen for a compaction test in the treated base, or in natural ground, should, whenever possible, have a plane and level surface. If other considerations make it advisable to choose a location with a rough surface, the top soil should be trimmed to as near a smooth and level surface as is feasible.

A hole, from 5 inches to 9 inches in diameter is cut or dug to the desired depth. Extreme care is necessary to make sure that all the soil removed from the hole is recovered and placed in a container. Similar care should be exercised to avoid picking up any soil from the surrounding surface. Precautions must be taken against loosening or compacting the material in the walls of the hole. If a rotating cutter, or auger, is used, the sides of the hole should be trimmed for at least 1/2 inch in order to remove any material compacted by the action of the cutter.

A large piece of heavy paper, sheet rubber or linoleum (with a hole in its center) placed on the ground before starting to dig the hole, will often facilitate the recovery of all excavated material.

If the moisture content of the soil in place is desired, a covered water-tight container should be used for the excavated material and the container should be kept tightly covered at all times except during the actual placing of soil therein. The tare weight of the container (including its cover) should be obtained before starting work and the gross wet weight of the soil and container should be obtained before the cover is removed.

Care should be exercised to remove and recover all loose material from the sides and bottom of the hole, and to avoid any undue loss of time which might permit excessive drying of the soil in the exposed walls of the hole.

When all excavated material has been recovered from the hole, the measuring funnel, or cone, is placed over the hole, large end down. The overflow vessel is set on top of the cone and rotated slightly to make sure it is seated properly on the shoulder at the bottom of the small cylindrical portion. Then the small regulating funnel is placed in the top of the overflow vessel as shown in Sketch 3. All parts of the apparatus have been machined in such a way as to insure their fitting together when assembled in the proper manner.

At the time of the test, there should be on hand, in closed containers or clean sacks, previously weighed units of a standardized sand whose weight per unit volume has been determined by means of equipment and methods identical with those described in the present instructions. One, or more, of these units of sand is next poured into the hole through the top funnel. The pouring is regulated so that the small funnel is kept filled to within approximately 3/4 of an inch of its top until sand begins to overflow at the top of the measuring funnel. Pouring is immediately stopped and the sand in the small funnel permitted to flow until the upper funnel is empty. The small funnel is then carefully removed and the overflow vessel, containing the excess sand, is again rotated gently to make sure it can be lifted freely from the measuring cone. Some settlement of the sand in the large cone will occur as the overflow vessel is rotated, but the exact quantity needed to fill the hole and the cone has already been determined by the original overflow. The excess sand in the overflow vessel is returned to the residue in the original container.

Care must be exercised at all times to avoid any jarring of the apparatus during the filling with sand until the small funnel has run empty. If nearby construction equipment causes any appreciable vibration of the ground, the unit weight of the sand will vary from that obtained by the standardized procedure.

The residual sand in the original container is weighed and the difference from the original quantity determined. This difference represents the weight of the sand in the hole plus the weight of sand required to fill the known volume of the cone. When the dry weight of the soil removed from the hole has been ascertained, the dry weight per cu. ft., may be computed by either one of the following formulae. (In order to obtain the greatest possible accuracy, it is recommended that weighings be made to the nearest gram on balances sensitive to 1 gram, or less. Hence formulae are for weights in grams.)

$$\frac{\dfrac{\text{Wt. of Sand Used}}{453.6}}{\text{Wt. per Cu.Ft. of Standardized Sand (Lbs.)}} = \text{Vol. of Sand (Cu. Ft.)}$$

$$\text{Vol. of Sand} - \text{Vol. of Cone} = \text{Vol. of Hole (Cu. Ft.)} \qquad \text{A}$$

$$\frac{\dfrac{\text{Wt. of Dry Soil}}{453.6}}{\text{Vol. of Hole (Cu. Ft.)}} = \text{Wt. in lbs. per Cu. Ft. of Material in Place.}$$

$$\frac{\text{Wt. of Dry Soil (Gm.)}}{\text{Wt. of Sand} - \text{Wt. of Sand in Cone (Gm.)}} \times \text{Wt. per Cu. Ft. of Sand} \qquad \text{B}$$

$$= \text{Wt. in Lbs. per Cu. Ft. of Material in Place}$$

The "Relative Compaction" may then be computed as follows:

$$\frac{\text{Wt. per Cu. Ft. in Place}}{\text{Standard Wt. per Cu. Ft. (By Laboratory Compaction)}} \times 100 = \text{Relative Compaction} \qquad \text{C}$$

As stated earlier in these instructions, a sand with rounded grains of nearly uniform size gives the most consistent results, but many local sands will be satisfactory for use with the above equipment. All sand used in volume measurements should be clean and dry, free from dust or an excess of grains smaller than 100 mesh in size and should not absorb or lose moisture, appreciably, with changes in the relative humidity of the air.

The Volume Measure is included in each Sand Volume Outfit in order to permit the field determination of unit weight for a standard sand. See Sketch 3. In determining the unit weight of a sand, the cone, cylinder, regulating funnel, etc., are set up on the flange of the measuring vessel and procedure outlined above is followed. The measure has been designed to be of approximately the same size as the ordinary hole dug in a cement treated roadway base course. If the apparatus is to be used to determine the volume of holes of a depth much greater than 12 to 15 inches, the unit weight of the sand should be determined in a vessel whose depth is approximately equal to that of the holes to be measured.

By deducting the weight of the residual sand from the total originally weighed out, the actual weight of sand in the cone and the measure is determined. The unit weight of the sand, in lbs. per cu. ft. may be calculated by the following formula:

$$\frac{\dfrac{\text{Wt. of Sand (In Grams)}}{453.6}}{\text{Vol. of Cone + Vol. of Measure (Cu.Ft.)}} = \text{Wt. of Sand in Lbs. per Cu.Ft.} \qquad \text{D}$$

All "Series A" Sand Volume outfits have been machined to a fixed identical volume of 1/6 cu. ft. (288.0 cu. in., or 4719.5 ml.) for the cone or the measure. Hence, the unit weight may be calculated as follows:

$$\frac{\text{Wt. of Sand in Grams}}{453.6} \times 3 = \text{Wt. in Lbs. per cu.ft.}$$

Chart II has been prepared to eliminate the need for calculations. The unit weight of the sand may be read directly from the curve when the weight required to fill the measure and the cone is known. If the unit weight of the sand is known, the weight in the cone alone may also be read directly from the curve.

The auxiliary ring is furnished for use inside the cone (see Sketch 3) if it is found advisable to use small holes or to economize on sand. With the ring in place, the volume inside the cone and ring is 1/7 cu. ft. and the weight of sand required to fill the ring and cone may be calculated as follows:

$$\text{Wt. of sand to fill Cone} \times 6/7 \text{ (or .857)} = \text{Wt. of sand for Cone and ring.}$$

The use of the ring in ordinary compaction tests is not recommended.

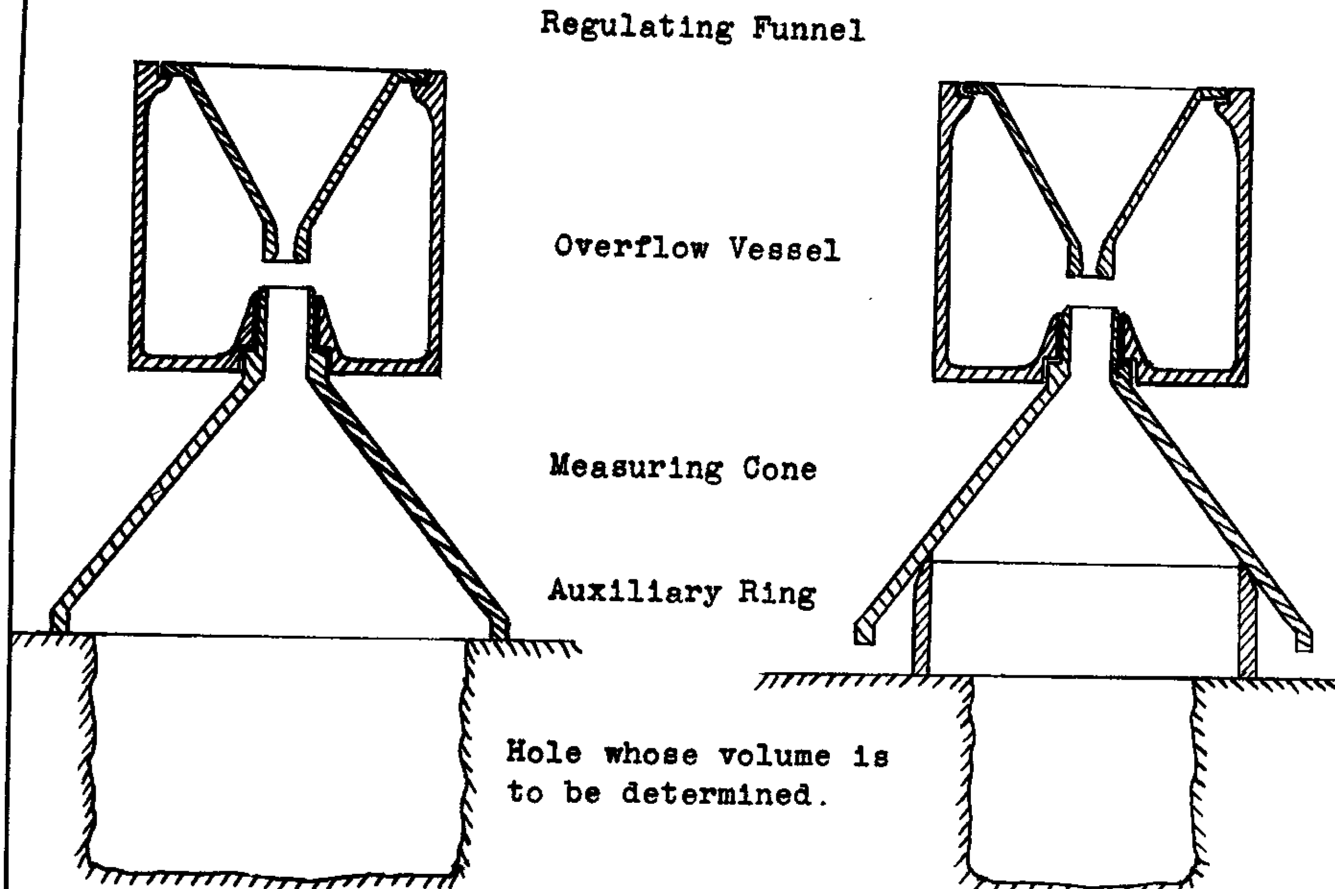
The large pan furnished with each outfit is for use in recovering sand for reuse. It is slipped under the cone before the latter is raised from the ground.

If care is used, most of the sand can be recovered from the holes without contamination. If the soil is moist, the sand should be dried before reuse.

A check standardization should be run at frequent intervals to make sure that the unit weights of the standard sand are remaining constant. If used in any other manner than with the apparatus described above, the unit weight of a sand is apt to vary from that determined by means of the Sand Volume Apparatus.

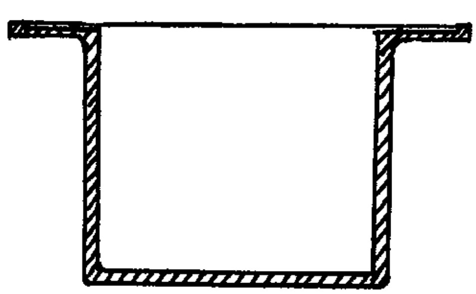
SKETCH 3

SAND VOLUME APPARATUS



Apparatus set up for normal use

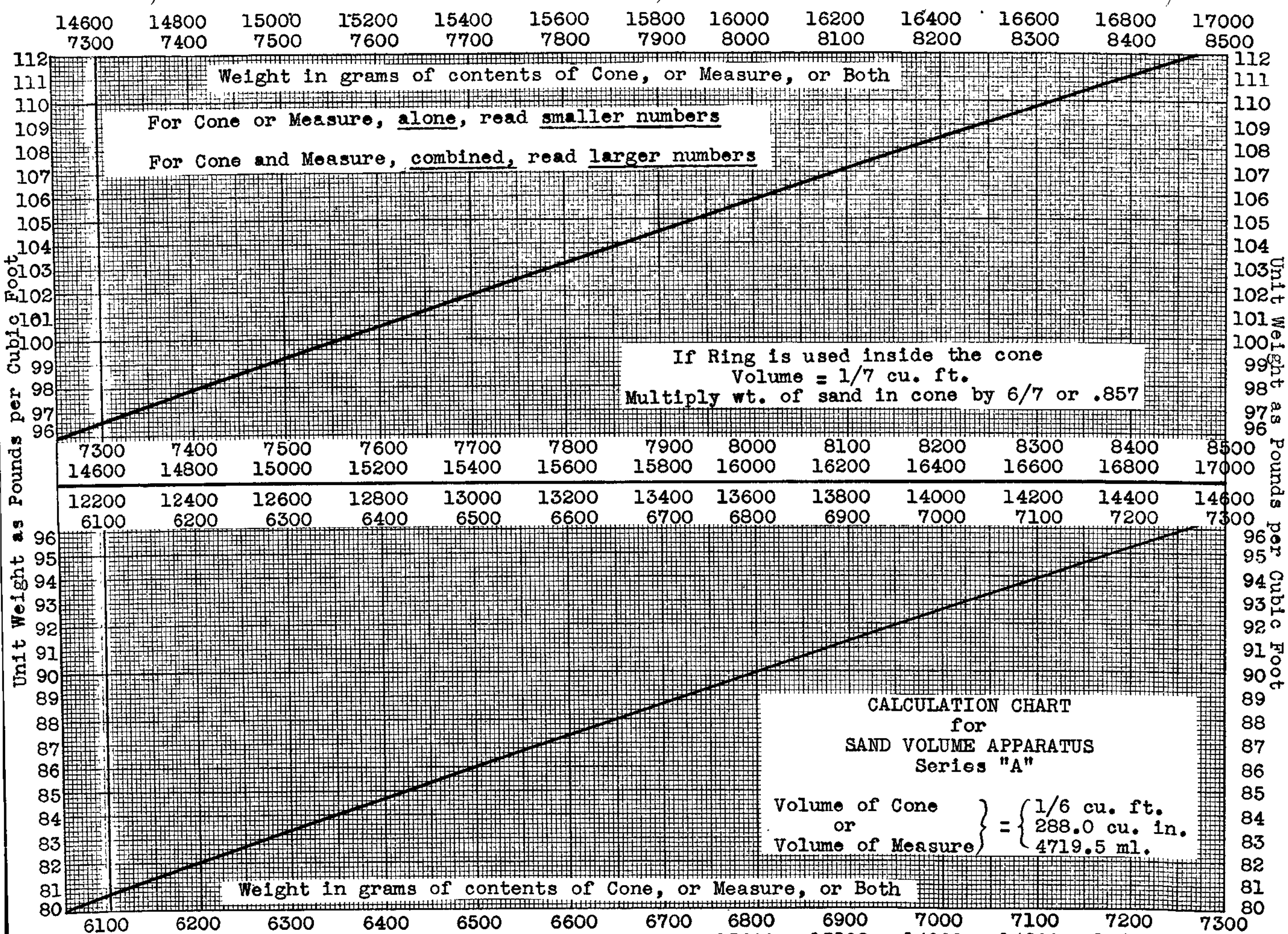
Apparatus set up when auxiliary ring is used



Volume Measure

Pour sand into the regulating funnel at a rate which will keep the funnel full to within 3/4" of top until sand begins to overflow at top of measuring cone. Stop pouring sand at instant of overflow. Allow small funnel to run empty before touching apparatus. <u>Do not jar apparatus until sand flow is completed</u>.

When apparatus is set on top of volume measuring for determination of unit weight of sand, be sure there are no sand grains under bottom edge of large cone.


Weight in grams of contents of Cone, or Measure, or Both
For Cone or Measure, alone, read smaller numbers
For Cone and Measure, combined, read larger numbers
If Ring is used inside the cone
Volume = 1/7 cu. ft.
Multiply wt. of sand in cone by 6/7 or .857
Unit Weight as Pounds per Cubic Foot
CALCULATION CHART
for
SAND VOLUME APPARATUS
Series "A"
Volume of Cone or Volume of Measure = 1/6 cu. ft. 288.0 cu. in. 4719.5 ml.
Weight in grams of contents of Cone, or Measure, or Both

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT

INSTRUCTIONS

FOR THE

FABRICATION OF TEST SPECIMENS

OF

CEMENT TREATED SOIL

March, 1942

STATE OF CALIFORNIA
Department of Public Works Division of Highways
Materials and Research Department

INSTRUCTIONS FOR THE FABRICATION OF TEST SPECIMENS OF CEMENT TREATED SOIL

March, 1942

INTRODUCTION

In the following instructions the term "soil" will be used to denote not only natural soils, but also screened or crushed aggregates or any other combination of various sized mineral particles proposed for use as a compacted roadway base after treatment with portland cement.

GENERAL INSTRUCTIONS

1. While widely different methods of combining the soil, water, and cement to produce the treated mixture may be employed according to circumstances, identical methods for fabrication of test specimens are used whether in the field or in the laboratory. Hence, it will be assumed that the soil has been thoroughly mixed with the proper amounts of portland cement and water and that the mixture is ready for compaction.

2. Inasmuch as it has been found impracticable to fabricate uniform or properly compacted test specimens of cement treated soil in standard 6" x 12" concrete cylinder molds, special methods have been developed and should be used for all projects involving cement treated base or any lean mixture requiring compaction on the street.

3. The procedure and equipment are described below and consist essentially of tamping and compressing the cement treated mixture in cylindrical metal containers 4" in diameter and 4" high.

4. The presence of rock particles larger than 1" in size in test specimens with a 4" diameter and 4" height is apt to result in erratic and erroneous test results. Hence, whenever coarse rock is present, the samples of treated soil should be screened through a 1" square mesh sieve to remove oversize material.

5. The number of control test specimens to be made each day should be determined by the Resident Engineer with due regard for local conditions, operating methods, quantity

7. All samples should be placed immediately in closed containers, (6" x 12" concrete cylinder cans for example), transported to the point of fabrication and made into specimens with the least possible delay in order to avoid any loss in possible compaction due to delays in handling the sample. Protection against the evaporation of moisture from the sample should be maintained at all times.

8. By reason of the equipment involved, a central room or shed for the fabrication of specimens is recommended. On some projects, however, the installation of fabricating, weighing and drying equipment in portable housing might be justified.

EQUIPMENT

9. The resident engineer should see that the following items of equipment, needed for the fabrication of test specimens of cement treated soil, are on hand.

1 - Balance with a capacity of 5000 to 20,000 gms. and a sensitivity of 0.02%, complete with weights.

1 - 4" Compaction Mold similar to the one shown on the attached Sketch 1, page 7.

1 - Tamper as shown on Sketch 1, page 7.

1 - 3-7/8" Metal Disc with 1/8" hole in center, also shown on Sketch 1, page 7.

1 - Measuring gauge as shown on Sketch 2, page 8, equipped with an Ames dial gauge reading to 0.001".

1 - 12 to 20 Ton Hydraulic Jack, mounted in a 30" Compression Frame as shown in Sketch 4, page 9. (For laboratory work a Compression Testing Machine usually replaces the above jack).

1 - Hot Plate or Oven capable of drying samples for Moisture Determinations. Miscellaneous small tools and equipment, including pans, brushes, scoops, spoons, spatulas, wrenches, funnels, etc.

1 - Special Bench Vise for holding Compaction Mold.

1-3 - Gross #5 x 1/2" Oval Headed Brass Wood Screws.

50-250*- Numbered Identification Discs (Copper Burrs) (Special series for each project).

50-250*- 4" x 4" Special Tin liners complete with caps.

25-50*- Shipping Cartons for shipment of test specimens.

* Dependent upon size of project and anticipated number of specimens to be made.

25 - 6" x 12" Concrete Cylinder Cans with lids.

5 - Doz. 10 yd. rolls of 1/2" Adhesive Tape.

Record Forms, fuel and miscellaneous supplies.

OPERATING PROCEDURE

10. Immediately upon its arrival at the point of fabrication, the sample of cement treated soil should be thoroughly mixed, then divided into the proper quantities for test specimens and moisture samples which are accurately weighed out. Moisture samples should be large enough to insure an accurate representation of the treated material, preferably 1000 gms., or more, especially if coarse rock is present. Care should be exercised in drying the moisture samples to avoid overheating, but, at the same time, to obtain thorough drying.

11. The weight of treated soil for each compaction specimen may be obtained from Chart 1, page 11, in accordance with the detailed instructions on page 10.

12. In separating the original samples for moisture samples, test specimens, etc., special care must be exercised to make sure that <u>each smaller sample contains the same proportion of fine and coarse material</u> as did the original sample.

13. The material for both moisture samples and test specimens should be weighed to the nearest gram and weighings should be made as rapidly as possible to avoid loss of moisture. Ordinary baking pans, approximately 9" x 5" x 4", make convenient weighing pans for use on Cenco balances. If a counter-weight for the empty pan is made by placing sand or shot in an 8 ounce (4" dia.) asphalt tin, weighing is facilitated and chances of error are reduced. All material for test specimens should be protected against loss of moisture after weighing and no delay should occur between weighing and fabricating.

14. For the fabrication of test specimens, the 4" mold is assembled with the tin liner in place and the plunger held one space from the bottom by means of the pin. (For some soils it may be necessary to hold the bottom plunger further from the end of the mold in order to prevent the rim of the mold from coming in contact with the shoulder of the plunger before compaction is completed. In such cases, insert the pin through successively higher holes until satisfactory results are secured). The extension sleeve is placed on top of the mold, then approximately half of the weighed sample is poured in. If rock larger than 1/4" is present, the treated soil should be rodded to prevent voids on the bottom or sides of the specimen. This layer is then tamped with the small end of the tamper until a degree of compaction is reached which is roughly equivalent to that obtained by a sheepsfoot roller. Usually the small end of the tamper will penetrate about 1/2"

of material processed each day, etc. A minimum of two specimens per day is recommended.

6. In deciding on the number of daily test specimens and whether the sample should be taken from the plant or the street the resident engineer should keep the following facts in mind:

a. Specimens compacted immediately from freshly mixed material secured at the mixing plant are necessary to fix the standard unit compacted dry weight; that is, the weight per cubic foot representing the best compaction obtainable under the most favorable conditions. These specimens should be made often enough to furnish an accurate average as a basis for calculating the relative degree of compaction actually secured on the roadbed. These plant samples will indicate any changes in materials or uniformity in mixing which may affect compaction.

b. With most soils under ordinary weather conditions a time interval between mixing and compaction will have a definite influence on the degree of compaction obtainable. Hence a certain number of test specimens should be fabricated from samples taken from the street. These samples should be taken just as the contractor's compaction operation is started and a comparison between the average unit dry weight of street samples and the average unit dry weight of plant specimens will show if delays in the contractor's operating procedure are having a detrimental effect on compaction and consequently on the strength of the base.

c. Tests for compressive strength on specimens manufactured by the field engineer can be taken to indicate the quality of the actual base if compacted to the same degree. Test specimens made from plant samples serve to establish a standard for each project and compaction tests made with the sand volume apparatus on the completed base will show the degree of compaction obtained and by comparison with the plant sample indicate whether the specification requirements are being met. In other words, compacted specimens from the plant may be taken as 100% compaction; differences in density and strength between plant specimens and street specimens probably are due to delays in compaction; differences between street specimen density and pavement density indicate inadequacies in the contractor's compaction equipment; differences between plant sample densities and densities on the roadway indicate the degree to which the contractor is achieving desired results, and failure to do so may be caused by delays in starting compacting, inefficient compaction methods or improper moisture content.

at the desired degree of compaction. Care must be taken to avoid the formation of a smooth compacted plane at, or near, the top of the first layer. The remainder of the soil is then added and the tamping, or the rodding and tamping, repeated. When the proper stage of compaction is again reached, the top is leveled off and lightly compacted with the large end of the tamper. Care should be exercised to have the finished top surface on an even plane at right angles to the axis of the mold. After hand tamping is completed the extension sleeve is removed.

15. Then the perforated disc is placed on top of the compacted soil, a small hole punched in the specimen through the center opening and the disc removed. One of the small oval headed screws is inserted in a small numbered copper identification washer, or burr, and pushed into the center hole. A numbered series of such washers should be obtained by requisition from the Headquarters Laboratory for each project in order to insure accurate identification of all specimens received for testing. Next, the top plunger is placed in position and the entire assembly placed on the hydraulic jack in the compression frame. If necessary, one or more of the spacing rings are placed between the top plunger and the top of the frame to prevent excessive travel of the jack. The pin holding the bottom plunger in place is removed and a total load of 25,000 lbs. is applied gradually, using one minute to attain the first 20,000 lbs., one-half minute for the next 5,000 lbs. and holding the 25,000 lbs. load for one minute. Then the load is released, the mold placed in the vise, the plungers taken out, the mold opened and the specimen in its tin jacket removed.

16. The specimen and container are immediately weighed, and the length is measured as shown in Sketch 2, page 8, using the top screw as a gauge point. See also detailed instructions on page 19.

17. The specimen identification number, whether plant or street, location from which the sample was obtained, weight and length of the specimen, and data from the corresponding moisture sample are recorded on the daily sample fabrication sheet in accordance with detailed instructions on pages 18-21 and examples on page 22. Then tin caps are placed on each end of the sample, first wrapping tape around the ends of the container to obtain a good fit for the caps. The specimen number is marked on the container with wax pencil before it is stored away for curing and shipment to the laboratory for testing.

18. As soon as the moisture sample is thoroughly dry its weights are recorded and the dry weight of the specimen is calculated. From the dry weight and the accurately measured length of the specimen, the equivalent compacted dry weight in pounds per cubic foot may be read from the attached conversion charts, as per instructions on page 12.

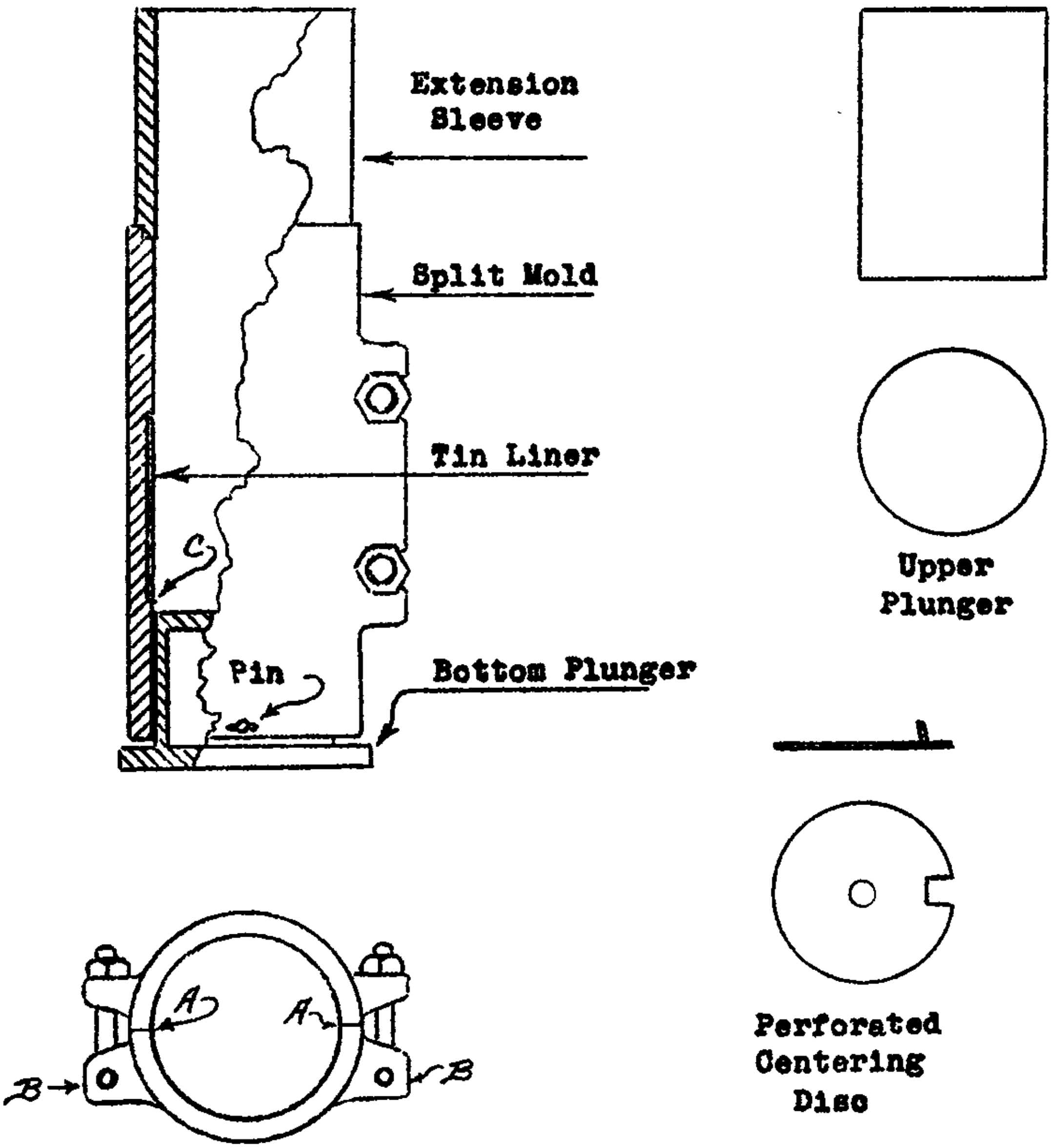
19. In order to avoid possible errors in the measurement of specimens, due to a change in the setting of the gauge, a standard steel calibration bar is provided with each unit. The length of the bar should be read on the Ames Dial at the beginning and end of each day's work.

20. With a bar 4.000" in length, the dial reading should be .500. If the reading is not within .001 of .500, the gauge should be adjusted so as to bring its reading within the specified limits.

21. Specimens should be shipped to the Laboratory on the second day following their fabrication but, if transportation conditions from the project to the Laboratory are such as to prevent the receipt of the sample on, or before, the morning of its sixth day, shipment should be made on the day following fabrication. Collapsible shipping cartons, holding 4 specimens each, are available for use, but shipment should not be held up in order to obtain a full carton each time. Corrugated metal shipping containers intended for concrete cylinders should not be used for cement treated base specimens because of unnecessary transportation expense.

SKETCH I

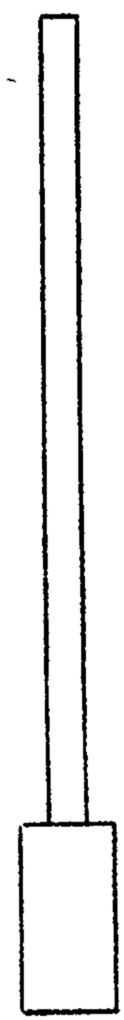
COMPACTION MOLD and ACCESSORIES



Compaction Mold - Hinged Bolt Type

Keep the mold clean and free from dirt or rust at all times. Grease lightly when not in use. Pay especial attention to cleaning all contact edges, "A" and the square shoulders of the recessed portion "C".

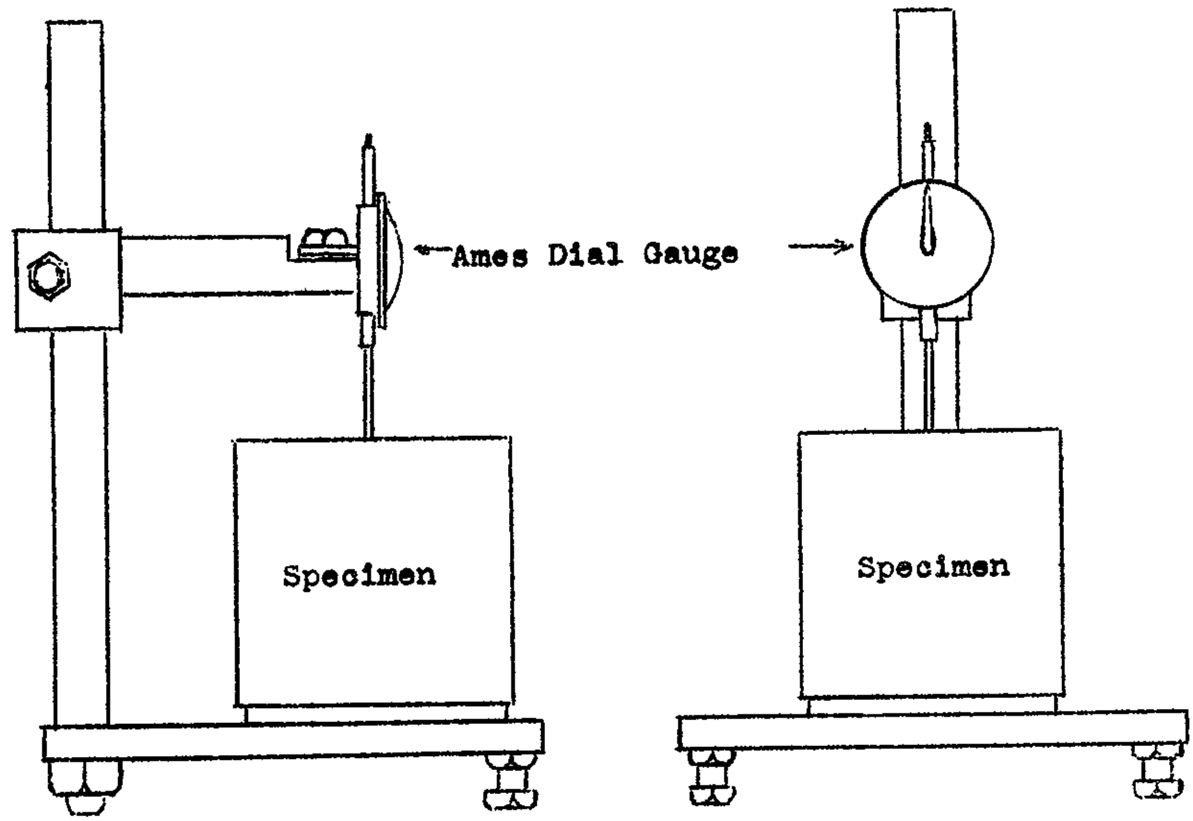
To assemble: Place the half to which the bolts are attached in the vise (which is furnished with the mold) so that the upright jaws of the vise grip the center of the lugs "B". Place a liner in the recessed section and rotate the liner to make sure it fits and is properly seated. Put the other half in place, making sure that the edges "A" are in contact before tightening bolts. Set up nuts by hand, being careful to tighten both sides evenly. Bring nuts to snug fit with wrench. Do not put any strain on them.

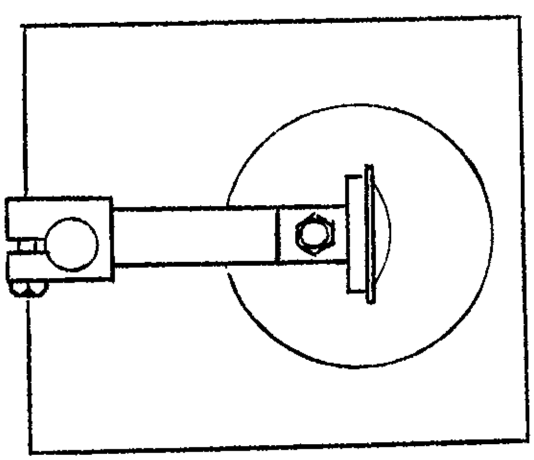


Tamper

SKETCH II

GAUGE FOR MEASURING LENGTH OF COMPACTED SPECIMENS





When measuring compacted specimens of soil, make sure that the raised disc on the base of the stand is clean and that no loose material is adhering to the bottom of the specimen.

Rest the extension arm of the gauge on the rounded screw placed in the top center of the specimen and move specimen slightly to check the reading.

Add the guage reading to 3.500" for actual length of specimen.

SKETCH IV

HYDRAULIC COMPACTION APPARATUS

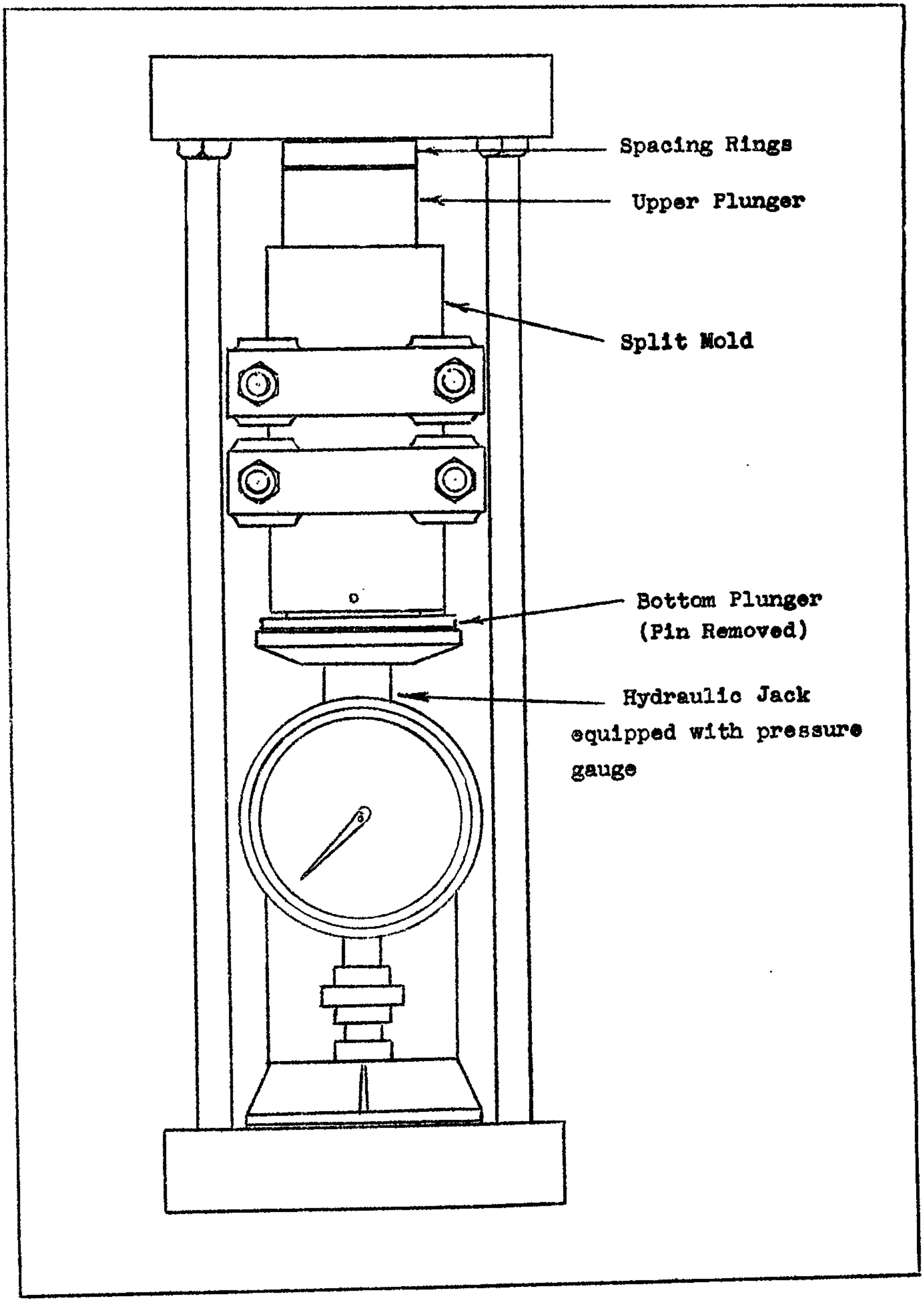
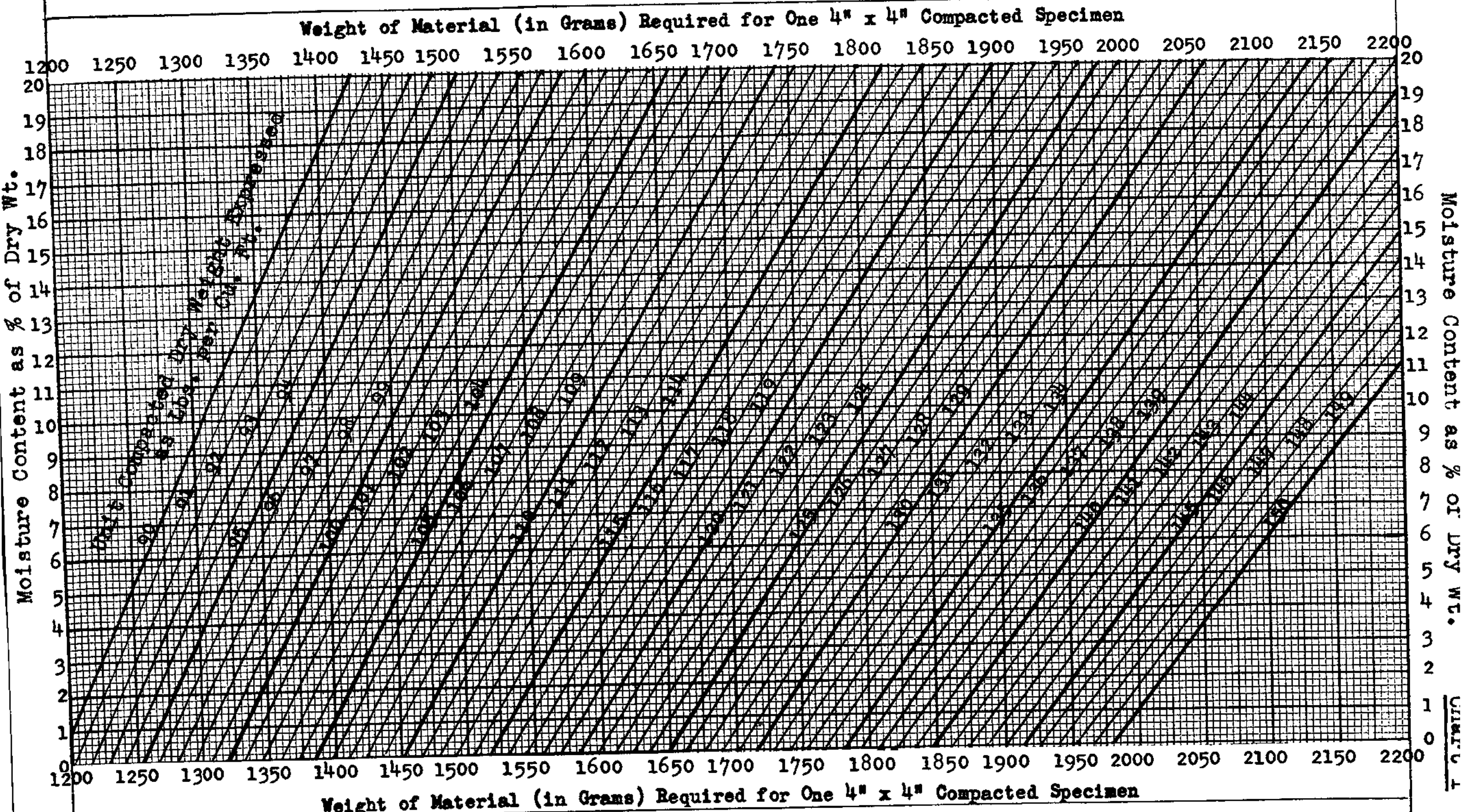


CHART I

MATERIAL REQUIREMENTS FOR 4" DIAMETER SPECIMENS



The point of intersection of the lines representing, respectively, the estimated unit compacted weight and the moisture content of the material to be used indicates the weight (in grams) required for a compacted specimen 4" in diameter and 4" long.

INSTRUCTION SHEET
FOR
CONVERSION CHARTS FOR 4" x 4" SPECIMEN

In order to eliminate the necessity for separate volume and weight calculations for each 4" x 4" specimen, a series of charts (A to E) have been prepared so that the compacted dry weight, expressed in pounds per cubic foot, can be read directly from the chart when the length and dry weight of the specimen are known. The charts cover lengths from 3.780" to 4.240" and unit compacted weights from 85 to 155 pounds per cubic foot.

The ordinates of the chart represent length of specimen in .001" increments and the abscissae represent the dry weights of specimens in grams.

After the specimen length has been measured by means of an Ames dial or a micrometer gauge and the dry weight calculated from the net wet weight and the moisture content, follow the lines indicating those respective values to their point of intersection. The inclined line immediately to the left of the point of intersection will show the whole number for the unit weight, expressed in pounds per cubic foot and the tenths of a pound may be estimated by interpolation of the point of intersection with respect to the adjacent inclined lines.

INSTRUCTION SHEET

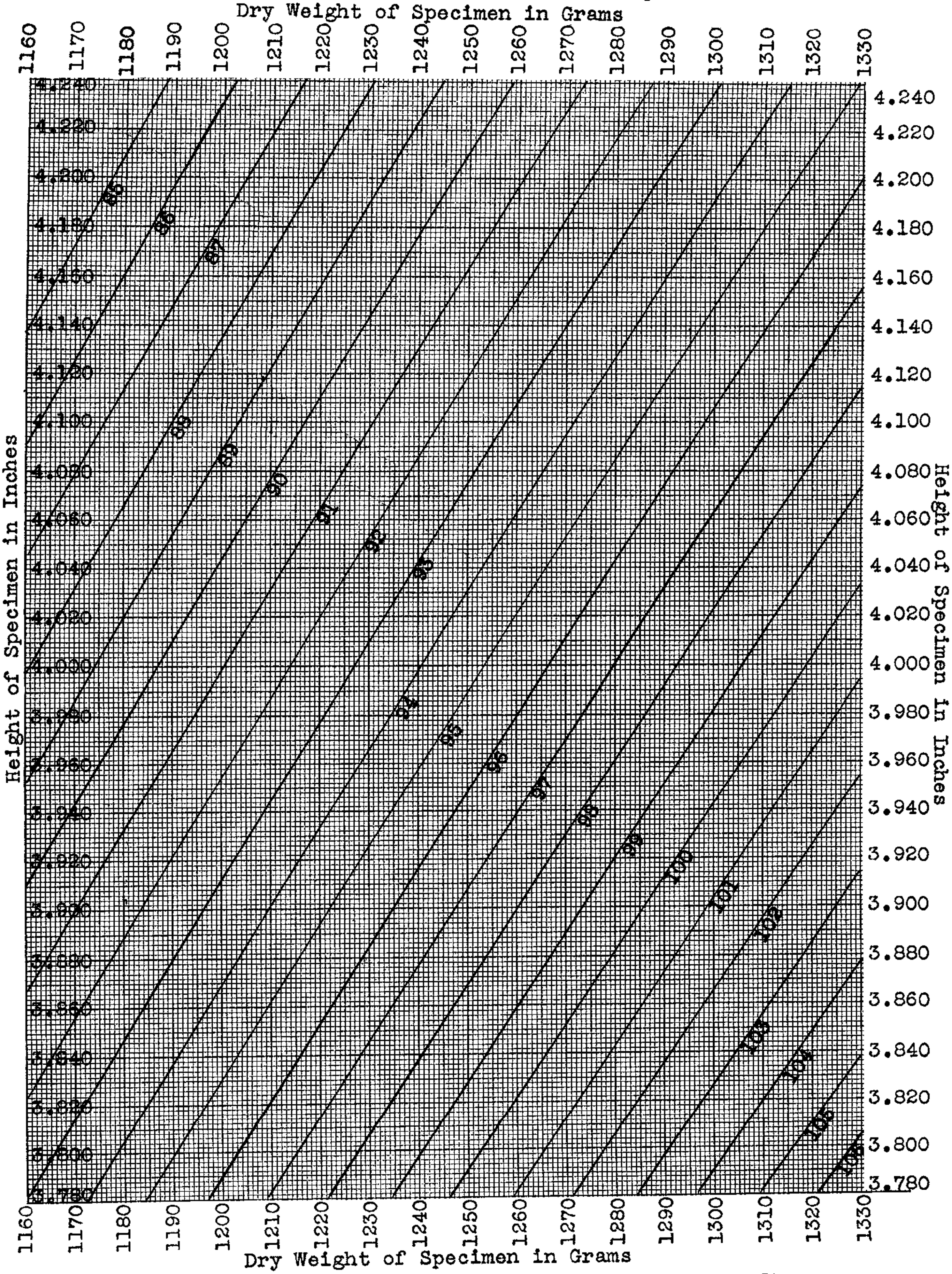
Chart I

Chart I has been designed to eliminate the calculations involved in determining the total weight of dry or moist material required for one 4" x 4" compacted specimen of soil, at various compacted unit weights and moisture contents.

In Chart I the ordinates represent the moisture content of the soil, expressed as per cent of the dry weight while the abscissa show the weight of material required for one compacted 4" x 4" specimen. The inclined lines show the unit compacted dry weight, expressed in pounds per cubic foot.

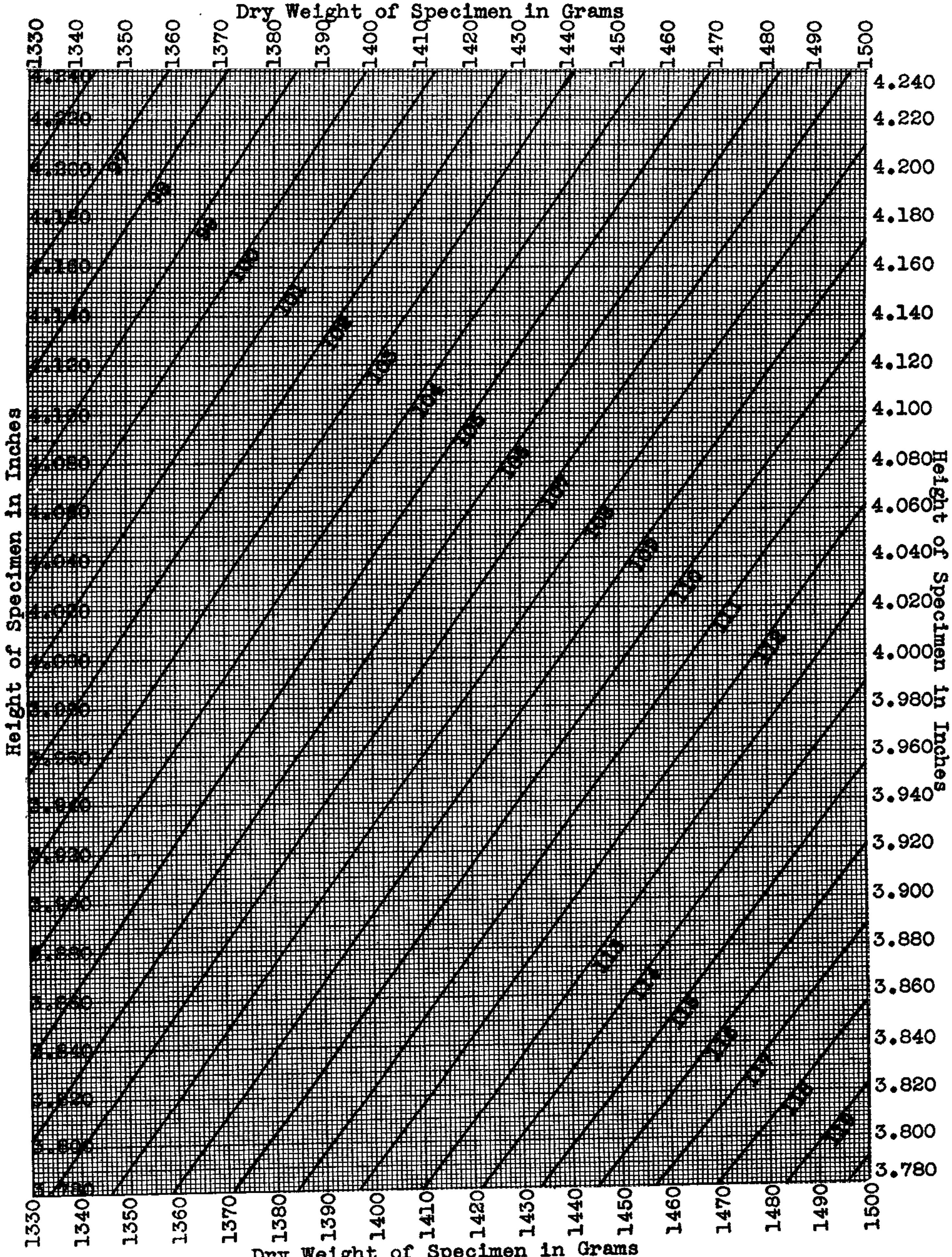
If a particular compacted weight per foot is anticipated, the line representing the weight is followed to its intersection with the horizontal line indicating the known or estimated moisture content. The vertical line passing through this point of intersection will show the total required weight of material including the moisture. If no clue exists as to the unit compacted weight, an estimate of the weight must be made and the above procedure followed. If the length of the specimen produced by use of the indicated weight of material is not within .200" of 4.000", then the estimate of compacted weight is revised in the light of the results from trial specimen and the process repeated.

Weight per Cu. Ft. for 4" Diam. Test Specimens



Oblique Lines Show Corresponding Weight in Lbs. per Cu. Ft.

Conversion Chart - Sheet B
Weight per Cu. Ft. for 4" Diam. Test Specimens

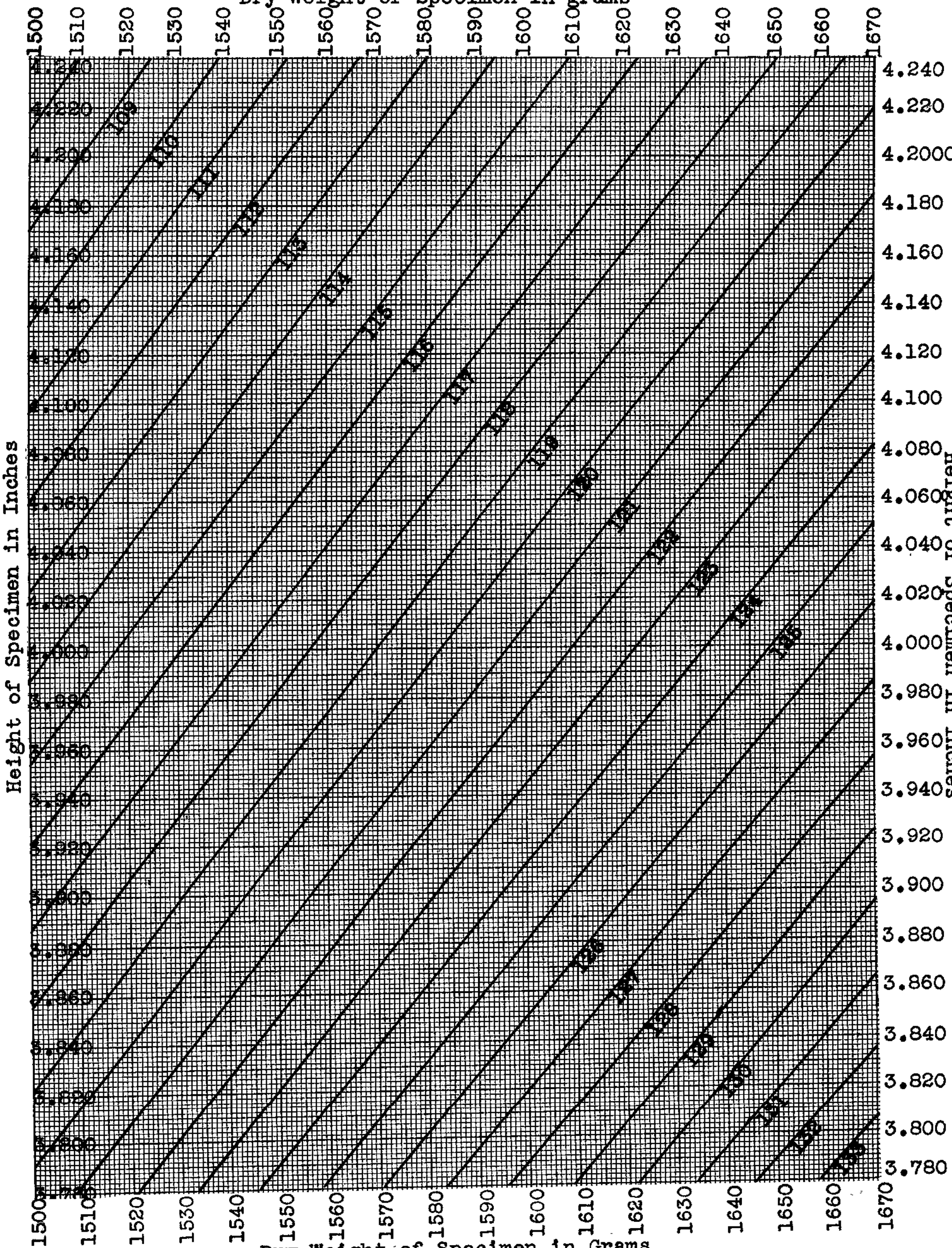


Oblique Lines Show Corresponding Weight in Lbs. per Cu. Ft.

Conversion Chart - Sheet C

Weight per Cu. Ft. for 4" Diam. Test Specimens

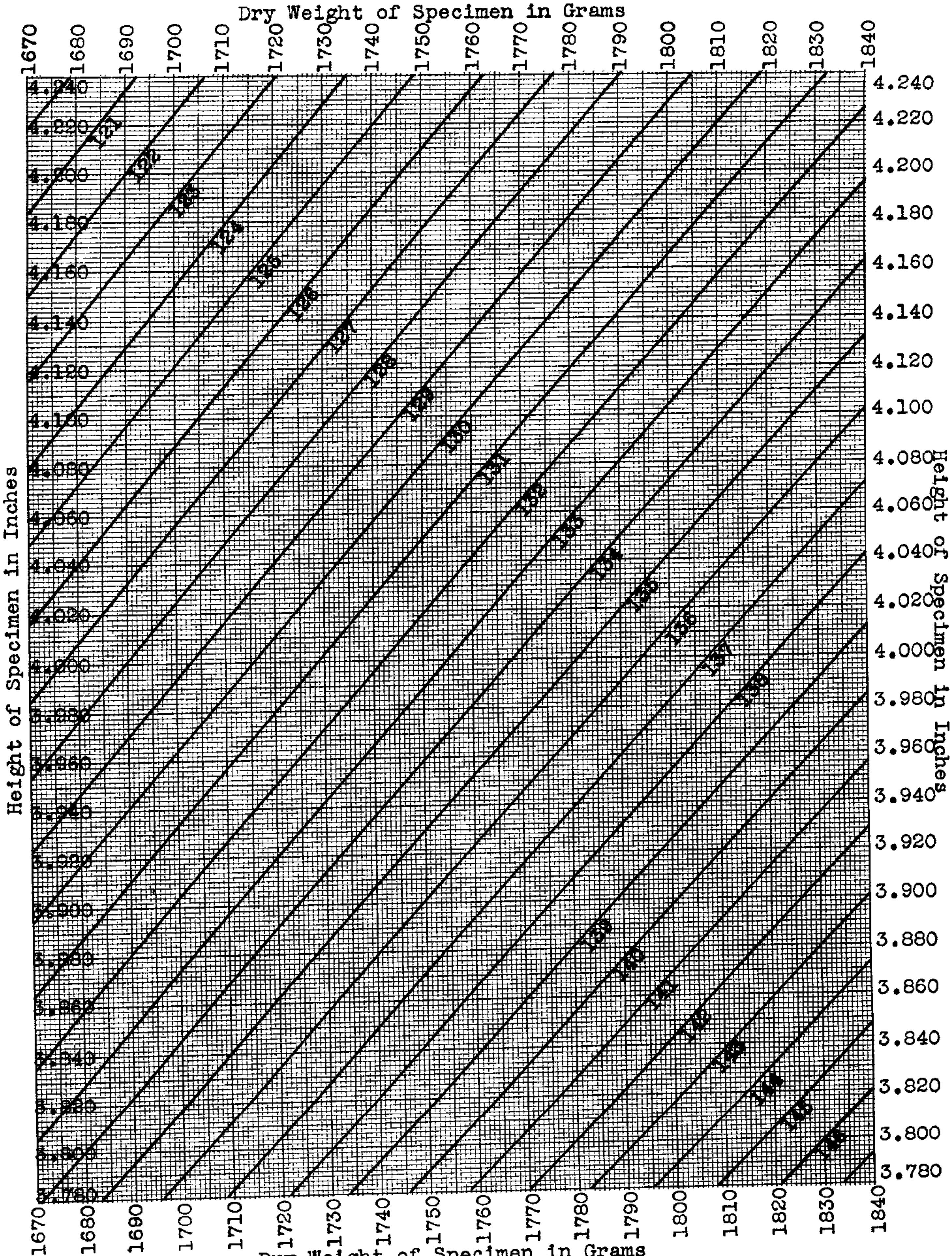
Dry Weight of Specimen in grams



Dry Weight of Specimen in Grams

Oblique Lines Show Corresponding Weight in Lbs. per Cu. Ft.

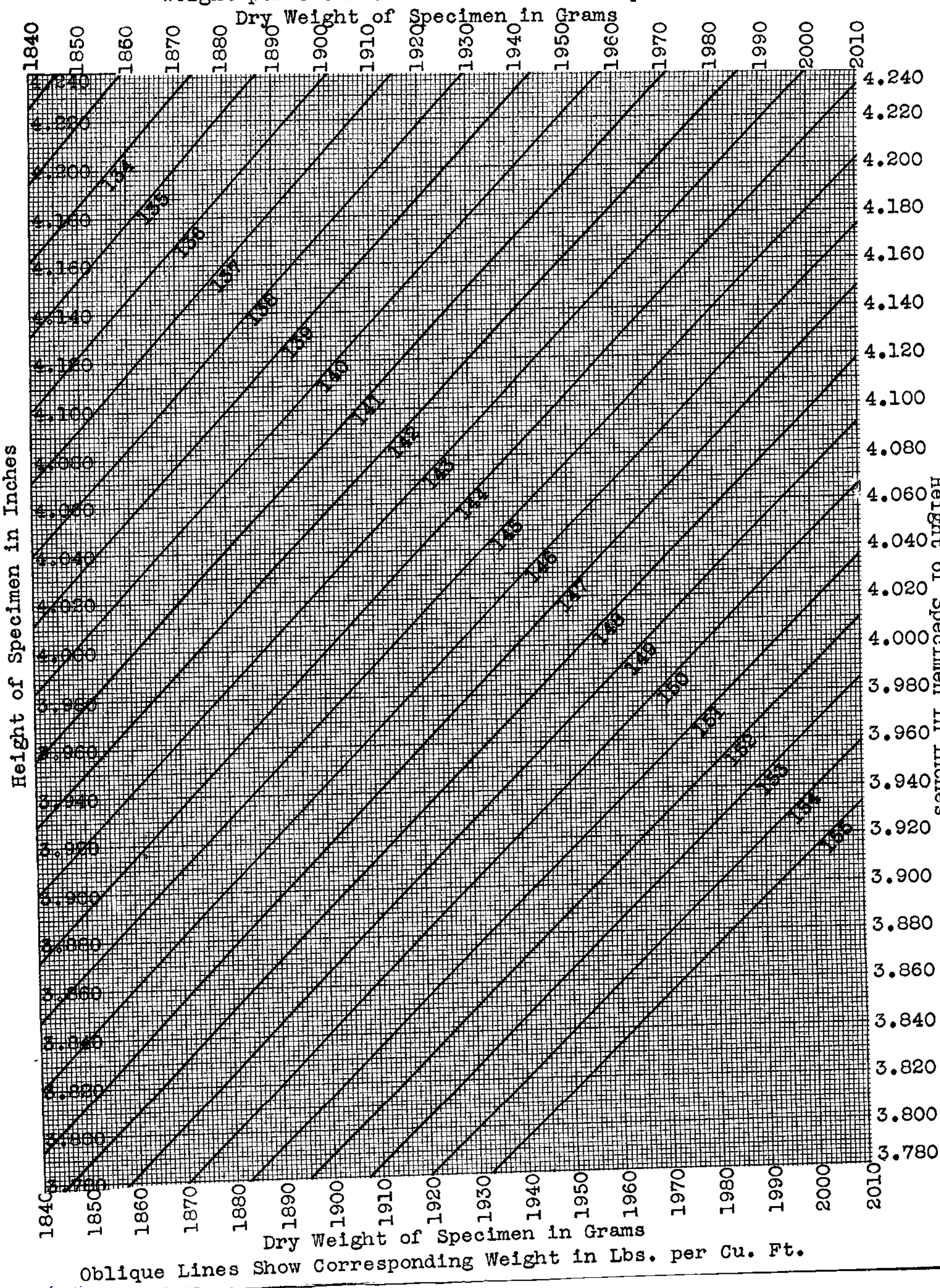
Weight per Cu. Ft. for 4" Diam. Test Specimens



Oblique Lines Show Corresponding Weight in Lbs. per Cu. Ft.

Conversion Chart Sheet 2

Weight per Cu. Ft. for 4" Diam. Test Specimens



FABRICATION OF TEST SPECIMENS, CONTINUED
DETAILED INSTRUCTIONS FOR WEIGHING, MEASURING AND RECORDING DATA

Attached hereto, as page 22, is an illustrative sample of Form T-333, "Fabrication Record for Field Test Specimens, Cement Treated Base Construction," on which typical entries have been made in red. The various columns have also been numbered at the top and the bottom of the page to facilitate reference to them in these instructions.

The contract data has been partially copied from an actual job record and the first two lines are self-explanatory. The third line shows the approximate average percentage of material passing the 1", the #4, and the #200 sieves as well as the name of the individual making the test specimen. It is not intended that this line shall show the exact grading at any one particular time but instead that it shall represent the approximate daily average. If a part of the aggregate is coarser than 1", the maximum size should be noted in the open space above remarks in column 9, until revised forms containing space for that information are available.

COLUMN 1

Column 1 is headed "Specimen Number" and is for recording the identification number of each test specimen. In order to avoid possible confusion or error, a special code letter, or letters, is assigned by Headquarters Laboratory to each cement treated base project and a quantity of small copper burrs are stamped with both identification letter and consecutive numbers. These identification washers will be furnished to the resident engineers upon request, and should be ordered by him in advance of actual construction.

In the example shown, letter "E" was assigned to Contract 28VC3 and individual specimens No. 96-E and 97-E and 98-E were fabricated on the day illustrated.

The identification washers are arranged in consecutive order on small threaded spindles, usually containing 50 each. One end of these spindles can be stuck into a nail hole or can be screwed into a small base plate, also furnished to each contract, so that the spindle stands upright and the washers can be picked off in consecutive order as needed. One of the washers is placed in the top of each specimen as noted in paragraph 15, page 5. The washers are countersunk to receive the oval headed screws and care should be taken to insert the screws properly so that the identification numbers will be uppermost on the finished specimen.

COLUMN 2

Column 2 shows the per cent of cement by weight (based on the dry weight of the untreated aggregate) that is actually added to the soil at the plant or on the road.

COLUMN 3

Column 3, headed "Sampling Data", is intended for recording the place and time of sampling. In the blank under "Station" should be shown the station at which the sample was obtained and, in case of a divided highway, the right or left half of the road, as the case might be. If the sample was secured at the mixing plant, then the station recorded should be the one at which the batch from which the sample was taken was subsequently placed in the road.

After "Time", should be entered the actual time of taking the sample and after "At" should be shown whether the sample was taken from the street or at the plant.

COLUMN 4

Column 4, headed "Can No.", is for use in identifying the moisture samples. In it should be entered the number, letter, or mark, which identifies the pan or container in which each moisture sample is placed.

COLUMN 5

Column 5, headed "Weights", is for the entry of moisture sample weights. The gross wet weight should be determined and entered on the sheet immediately upon the removal of the moisture sample from the rest of the treated material. See paragraph 13, page 4. The gross dry weight should be noted as soon as all the moisture has been driven off from the sample and before the dried soil can absorb atmospheric moisture. The tare weight represents the weight of the container. If weighing pans provided with balanced counterweights are used, the tare will be zero. The net dry weight represents the actual weight of the dried soil and is obtained by deducting the tare from the gross dry weight of the sample and container. The loss is the difference between the wet and the dry weights (soil weighed in same container each time) and represents the weight of water originally present in the sample.

The percentage of moisture is based on the dry weight of the soil and is obtained by dividing the loss in weight during drying by the net dry weight of the soil after drying.

COLUMN 6

In Column 6, headed "% of Dry Weight", should be entered the % of moisture for the soil, calculated as described above. If two or more moisture determinations are made on the same sample, their average should be calculated and entered as such in the same column. Note 97-E.

COLUMN 7

In Column 7, headed "Dimensions, Weights, etc.", are entered the appropriate data for each specimen. As soon as the specimen has been weighed, its length is measured accurately by means of an Ames dial gauge mounted on a stand as shown in Sketch 2, page 8. One of these gauges, complete with stand, is furnished with each compaction outfit. The specimen is set on the raised disc of the base plate with the small screw in the top of the specimen directly under the point of the gauge. The point of the gauge is brought into contact with the top of the screw and the specimen moved slightly to make sure the gauge is resting on the highest part of the screw. Care must be exercised to keep the base plate and the gauge clean at all times. The gauge is read to the nearest 0.001" and the reading recorded after the word "Gauge" in Column 9. The reading is then added to 3.500" and the sum is recorded in Column 7 after the word "Length". For example, on page 22 a gauge reading of 0.530 on specimen 96-E is equivalent to a length of 4.030" for the specimen.

The arm holding the Ames dial is adjusted on the post so that the gauge reads 0.500 when the point is placed on a test bar 4.000" long. In other words, when the dial reads 0.000 the distance between the point of the gauge and the base plate is 3.500".

The specimen in its metal sleeve is weighed to the nearest gram immediately upon removal from the mold. Any free water or loose soil adhering to the outside of the tin sleeve should be wiped off before the weight is determined. The weight of specimen and its tin container is recorded as gross wet weight in the space marked "Gr. Wt." The Tare weight of the sleeve (or liner) is recorded in the space marked "Tare" and subtracted from the gross wet weight to obtain the net wet weight of the compacted soil. The latter figure is entered in the space marked "Net Wt." (Liners are furnished by the Laboratory upon requisition and are marked with their tare weights before shipment.)

The net wet weight of the compacted specimen is divided by 100 plus the per cent of moisture as determined above, (Column 6) to obtain the net dry weight which is entered in the space marked dry weight.

Charts A, B, C, D, and E, pages 13-17 inclusive, have been prepared to eliminate the calculations involved in converting the net dry weight of the specimen into equivalent lbs. per cu. ft. To use the charts, find the ordinate corresponding to the net dry weight of the specimen in grams and follow that ordinate to its intersection with the abscissa corresponding to the length of the specimen. The point of intersection, read with reference to the heavy inclined lines, shows the corresponding value in lbs. per cu. ft.

There will usually be a slight difference between the net wet weight of the compacted specimen and the original weight of sample used due to small mechanical losses of material. Each operator should note his average loss which, however, should be under 5 grams.

When water is squeezed out of the treated soil during compaction the quantity should be noted and checked by observing the difference in weight between the sample and the compacted specimen. By deducting the normal loss from the total loss, the amount of water squeezed out of the material may be estimated with reasonable accuracy and the water loss so estimated should be entered opposite "H_2O Out" in Column 9. The weight of the water squeezed out should be added to the net wet weight of the specimen before calculating its net dry weight because the moisture content used for calculation represents the moisture in the soil at the start of compaction and not the residual moisture after part has been squeezed out. See specimens 97-E and 98-E on page 22.

COLUMN 8

The compacted dry weight per cu. ft., calculated as described above, is recorded in Column 8.

COLUMN 9

In Column 9, headed "Remarks, etc.", blanks have been provided for the recording of sample weights, gauge readings and the amount of water squeezed out during compaction and the proper entries in those spaces should be made as described above under Column 7. In the blank spaces any additional remarks may be entered.

[illegible] OF CALIFORNIA
[illegible] DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT
[illegible] TEST SPECIMENS
CEMENT TREATED BASE CONSTRUCTION

[illegible] No. [illegible] Dist. [illegible] Co. [illegible]
[illegible] Meth. [illegible] Date [illegible]
[illegible] Pass [illegible]

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
		Sta., Time, Data		MOISTURE Weights	% of Dry Wt.	SPECIMEN DATA Dimensions Weights etc.	Dry Wt. Per Cu. Ft.	REMARKS etc.
		Station [illegible] [illegible] Time [illegible] At [illegible]		Gr. Wet [illegible] " Dry [illegible] Tare [illegible] Net Dry [illegible] Loss [illegible]	[illegible]	Length [illegible] Gr. Wt. [illegible] Tare [illegible] Net Wt. [illegible] Dry Wt. [illegible]	[illegible]	Sple. Wt. [illegible] Gauge [illegible] H2O Out [illegible]

The above entry is typical for a sandy or gravelly material showing no loss of water during compaction.

The following entries are for typical specimens of similar material with a higher moisture content, and a resultant water loss during compaction.

[illegible]	[illegible]	Station [illegible] Time [illegible] At [illegible]		Gr. Wet [illegible] " Dry [illegible] Tare [illegible] Net Dry [illegible] Loss [illegible]	[illegible]	Length [illegible] Gr. Wt. [illegible] Tare [illegible] Net Wt. [illegible] Dry Wt. [illegible]	[illegible]	Sple. Wt. [illegible] Gauge [illegible] H2O Out [illegible]
[illegible]	[illegible]	Station [illegible] Time [illegible] At [illegible]	[illegible]	Gr. Wet [illegible] " Dry [illegible] Tare [illegible] Net Dry [illegible] Loss [illegible]	[illegible]	Length [illegible] Gr. Wt. [illegible] Tare Net Wt. [illegible] Dry Wt. [illegible]	[illegible]	Sple. Wt. [illegible] Gauge [illegible] H2O Out [illegible]
		Station Time At		Gr. Wet " Dry Tare Net Dry Loss		Length Gr. Wt. Tare Net Wt. Dry Wt.		Sple. Wt. Gauge H2O Out
		Station Time At		Gr. Wet " Dry Tare Net Dry Loss		Length Gr. Wt. Tare Net Wt. Dry Wt.		Sple. Wt. Gauge H2O Out
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT

INSTRUCTIONS
FOR THE
DETERMINATION OF THE OPTIMUM
MOISTURE CONTENT OF A CEMENT
TREATED SOIL

March, 1942

STATE OF CALIFORNIA
Department of Public Works Division of Highways
Materials and Research Department

INSTRUCTIONS FOR THE DETERMINATION OF THE OPTIMUM MOISTURE CONTENT OF A SOIL

March, 1942

When soils, or other combinations of various sized particles of mineral aggregates, are mixed with different quantities of water and then compacted by identical methods, one certain moisture content will usually produce a greater density (as indicated by the compacted dry weight of material for a given volume) than will be the case with any other moisture content for the particular material under consideration. The amount of water thus required for maximum compaction, expressed as per cent of the dry weight of the material, is commonly referred to as the "Optimum Moisture Content" for that soil or aggregate.

Different methods of compaction usually show different moisture contents as optimum for the same material. Therefore, the value for "Optimum Moisture" only applies <u>to a given method and degree of compaction</u>. The method outlined below gives results which are comparable with those obtained on the road by ordinary construction equipment in use on California highways and is the one used at the present time by the Materials and Research Department in the study of soils or aggregates proposed for use in cement treated bases.

The term "soil" as used in the following instructions includes not only natural soils but also graded or crushed aggregates and any other combination of various sized particles proposed for cement treatment.

Optimum moisture tests are made usually on cement treated, on untreated soils, or on both, depending upon the information desired. The method is the same in each case, but, where treated soils are to be tested, the proper quantity of portland cement should be mixed with the soil before the addition of water. If coarse rock (above No. 4 mesh) is present in the sample, it is usually preferable to mix the cement with the minus No. 4 mesh portion of the sample.

The proper proportioning of soil, water, etc., is facilitated by the use of dry material but a moist sample may be used if its moisture content is known and is not above that desired for use in the test.

No rock particles coarser than those which will pass a 1" square mesh sieve should be used in optimum moisture tests involving 4" diameter specimens. If particles coarser than 1" are to be used in actual construction, the quantity of rock between the No. 4 mesh and the 1" in the portion of the sample to be used for optimum moisture tests should be adjusted to compensate for the amount of oversize screened out.

EQUIPMENT

The equipment required for optimum moisture determinations includes the following items:

1 - Balance with a capacity of 5,000 to 20,000 gm. and a sensitivity of 0.02%, complete with weights

1 - 500 cc. graduated glass cylinder

1 - Compaction Mold, similar to the one shown in the attached Sketch 1, page 7

1 - Tamper as shown in Sketch 1

1 - Measuring gauge as shown in Sketch 2, page 8, equipped with Ames Dial reading to 0.001"

1 - 3-7/8" diam. metal centering disc with 1/8" hole in center

1 - Gross #5x1/2" Oval Headed Wood Screws

1 - Mechanical Mixer or facilities for hand mixing

1 - 12 to 20 Ton Hydraulic Jack with Compression frame, and Pressure Gauge, as shown in Sketch 4 or a Compressing Testing Machine of 25,000 lbs., or greater, capacity

1 - Oven, or hot plate, for moisture determinations

1 - Special Bench Vise for holding Compaction Mold

Special liners for mold, pans, spatulas, spoons, etc.

OPERATING PROCEDURE

If no previous data on the soil in question is available, a trial initial moisture content may be estimated from the appearance of the soil or from its sieve analysis. Usually tests are started with a moisture content below the expected optimum. As a rule, an initial moisture of 3% to 7% depending upon the type of soil, will give a good starting point.

Chart I, attached, shows the dry weight, and the moist weight, of material required for one 4" x 4" specimen for varying percentages of moisture and different compacted dry weights. The dry weight of soil, or of soil and cement, used at the start of each test may correspond to the exact amount shown on the chart for the estimated compacted weight or may be in excess of the estimated weight, depending upon the method of mixing to be used and the experience of the operator. When no previous data is available, it is advisable to assume sample quantities for the first specimen on an estimated 120 lbs. per cubic foot and adjust subsequent samples according to the indications provided by the size of the initial specimen.

Enough water is added to the sample to bring its moisture content to the desired trial amount, then the soil and water are thoroughly mixed. If the exact estimated weight for a compacted specimen has been used, all of the mixture will be needed for compaction, but if more than the required amount of soil was used at the start, then the exact quantity of moistened soil indicated by Chart I, page 11, for the estimated weight and moisture will be used for compaction.

If the sample contains rock particles coarser than No. 4 mesh (note paragraph 3, page 2) each individual sample should be separated on the No. 4 sieve and the coarse particles thoroughly saturated by immersion in water. The water, or the cement and water, should be mixed with the fine portion of the sample, as noted above, then the saturated coarse material should be surface dried and uniformly mixed with the fines before starting compaction.

The 4" compaction mold shown in Figure 1 is set up with the tin liner in place and the lower piston held in position by the pin in the first hole above the bottom one. Half of the proper weight of moistened soil is placed in the mold and tamped with the small end of the tamper until the tamper penetrates approximately 1/2" with each blow. (It is the intent to accomplish, in the above tamping, a compacting as near as is possible to that produced by effective sheepsfoot rolling.) Then the second half of the soil is added and the tamping with the small end of the tamper is repeated. Care must be exercised to avoid any loss of material during transfer of the sample or its subsequent tamping, etc. After reaching the desired compaction in the top layer, the surface of the sample is further compacted by a few blows of the large end of the tamper, care being taken to secure an even surface, at right angles to the axis of the mold. If coarse rock is present, each layer should be rodded with a 3/8" rod 15 to 30 time before tamping in order to eliminate large voids.

An oval, or a round headed, #5 x 1/2" wood screw is inserted for a gauge point in a small hole punched in the center of the upper surface of the specimen, using the perforated disc to locate the center, after which, the upper plunger is placed in position. The assembled mold is then placed in the compression machine, the pin removed from the lower plunger and pressure applied.

The load is applied gradually, using one minute to bring the total pressure on the specimen to 20,000 lbs., one-half minute more to raise the load from 20,000 to 25,000 lbs. and then holding the 25,000 lb. load for one minute before it is released.

As soon as the pressure is released, the compacted specimen (together with the liner which now forms a container for the specimen) is removed from the mold, weighed and then measured for length as shown in Sketch 2. Weights, gross and tare, and the length of the specimen are recorded on sheets provided for that purpose. If water is squeezed out during compaction, a notation is made of the difference between the net wet weight of the specimen and the net wet weight of sample used. Then the tin jacket is removed from the specimen and the latter broken up and its moisture content determined by drying the entire specimen.

If water has been squeezed out of the specimen during compaction and no appreciable loss of material occurred in handling or compacting, the original net wet weight of the sample placed in the mold is used in computing the moisture content instead of the net wet weight of the compacted specimen.

A new sample of the soil is mixed with 1 to 2% more water than was used in the original test and the process is repeated. Successive specimens are molded with increasing water content until the mixture becomes plastic or loses an excessive amount of water when under the compacting pressure. (See note on next page.)

If the initial specimen varied by more than 0.200" from 4.000" in length, the weight of raw soil is changed so as to bring the compacted specimen nearer the desired 4.000" length, bearing in mind that successive specimens should be more thoroughly compacted (as the optimum moisture content is approached) and hence will be shorter for the same weight of dry soil.

The unit compacted dry weight of soils is usually expressed in pounds per cubic foot. It is computed from the net dry weight and the length of each compacted specimen. Conversion charts "A" to "E", pages 13 to 17, inclusive, have been prepared to facilitate such computations. Detailed instructions for use of these charts are given on page 12.

The "Optimum Moisture Content" is determined by a comparison of the unit compacted dry weights obtained with varying moisture contents. It is the moisture content which produces the highest compacted dry weight. The most convenient method for its determination is to plot the results of the various tests on a sheet of coordinate paper, using the moisture contents (in % of dry weight) as abscissae and the unit compacted dry weights as ordinates, drawing a smooth curve through the various points so located. The moisture content at which the peak of the curve occurs is considered the optimum. If coordinate paper is not available, the results may be tabulated and compared to obtain the same information.

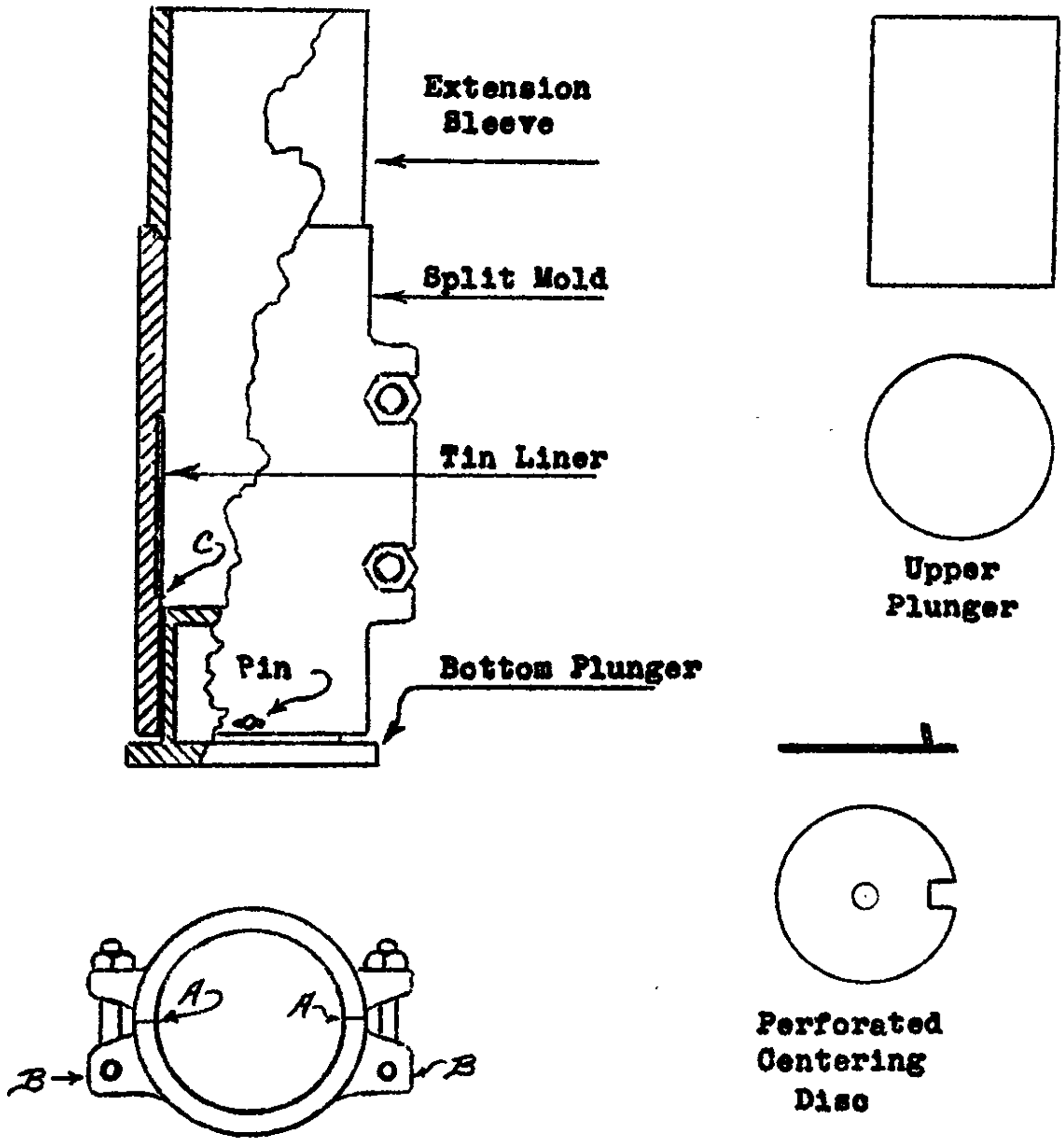
A fresh sample of soil should be used for each determination because many soils are altered by compaction and repeated use of the same soil may lead to erroneous results.

Note: With soils composed largely of granular particles, comparatively free of clay or colloids, and especially with clean graded aggregates, it will usually be found that maximum compacted dry weights are obtained when water is squeezed out of the specimen during the application of the static load. However, the water content which will produce maximum compaction under the above conditions will at times cause the treated material to become quaky and to move under the compacting equipment used in actual construction. Hence, in the field, it may be necessary to use less than the theoretical "Optimum Moisture Content", determined as described above, whenever the base develops a quaking or jelly-like appearance under the rollers or other compacting equipment.

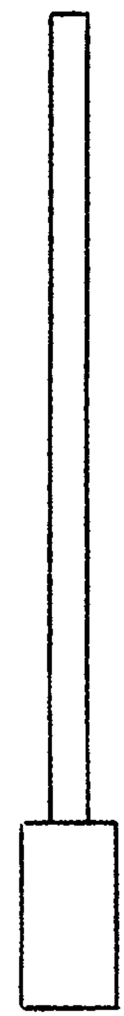
In recommending the quantity of moisture to be added during cement treatment in the field, evaporation losses due to climatic conditions, methods of handling, etc., must be taken into account and allowances made for such losses.

SKETCH I

COMPACTION MOLD and ACCESSORIES



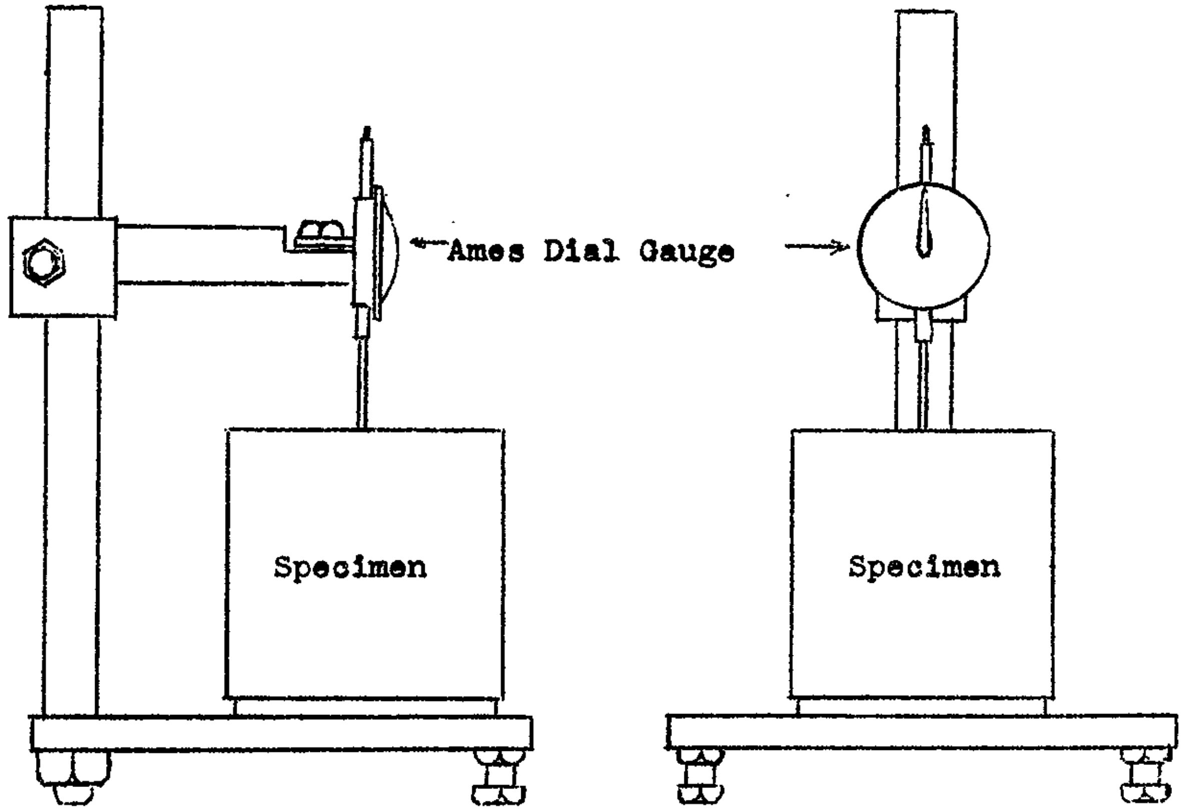
Compaction Mold - Hinged Bolt Type

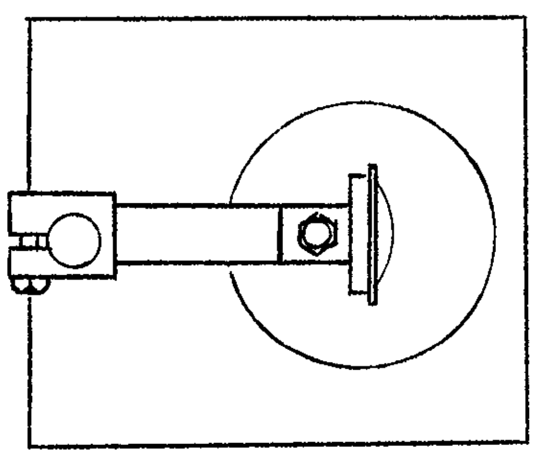


Keep the mold clean and free from dirt or rust at all times. Grease lightly when not in use. Pay especial attention to cleaning all contact edges, "A" and the square shoulders of the recessed portion "C".

To assemble: Place the half to which the bolts are attached in the vise (which is furnished with the mold) so that the upright jaws of the vise grip the center of the lugs "B". Place a liner in the recessed section and rotate the liner to make sure it fits and is properly seated. Put the other half in place, making sure that the edges "A" are in contact before tightening bolts. Set up nuts by hand, being careful to tighten both sides evenly. Bring nuts to snug fit with wrench. <u>Do not put any strain on them</u>.

GAUGE FOR MEASURING LENGTH OF COMPACTED SPECIMENS





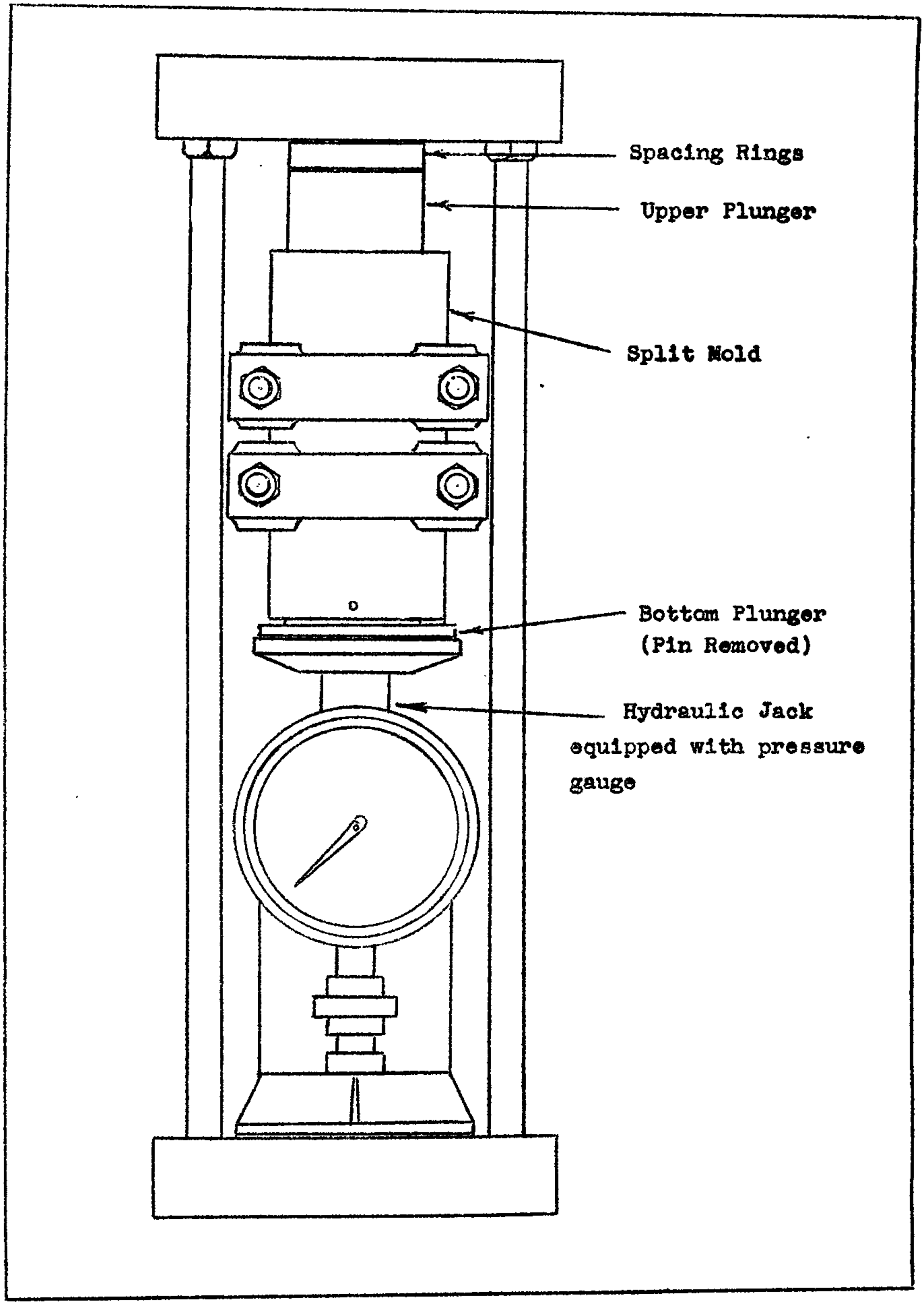
When measuring compacted specimens of soil, make sure that the raised disc on the base of the stand is clean and that no loose material is adhering to the bottom of the specimen.

Rest the extension arm of the gauge on the rounded screw placed in the top center of the specimen and move specimen slightly to check the reading.

Add the guage reading to 3.500" for actual length of specimen.

SKETCH IV

HYDRAULIC COMPACTION APPARATUS



INSTRUCTION SHEET

Chart I

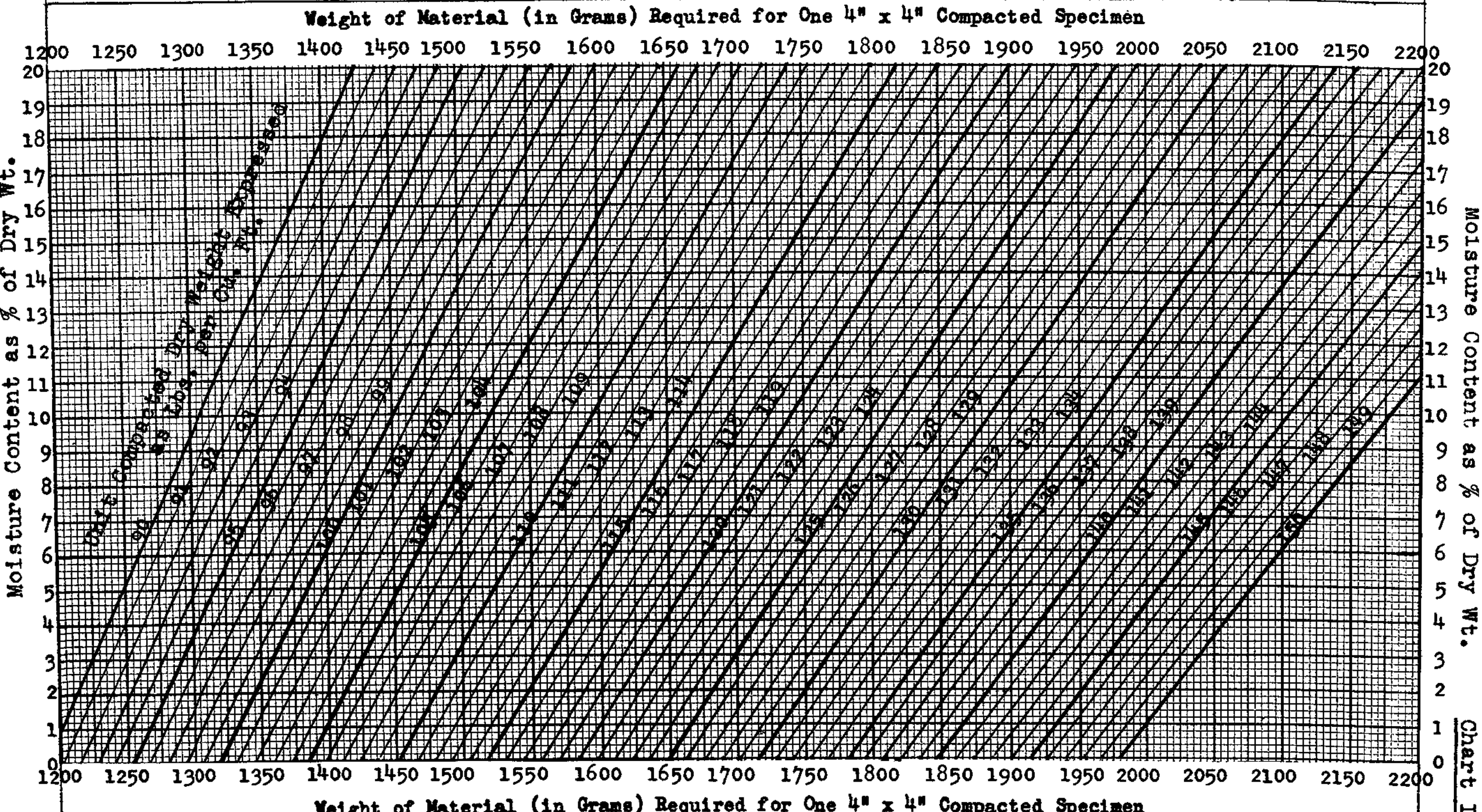
Chart I has been designed to eliminate the calculations involved in determining the total weight of dry or moist material required for one 4" x 4" compacted specimen of soil, at various compacted unit weights and moisture contents.

In Chart I the ordinates represent the moisture content of the soil, expressed as per cent of the dry weight while the abscissa show the weight of material required for one compacted 4" x 4" specimen. The inclined lines show the unit compacted dry weight, expressed in pounds per cubic foot.

If a particular compacted weight per foot is anticipated, the line representing the weight is followed to its intersection with the horizontal line indicating the known or estimated moisture content. The vertical line passing through this point of intersection will show the total required weight of material including the moisture. If no clue exists as to the unit compacted weight, an estimate of the weight must be made and the above procedure followed. If the length of the specimen produced by use of the indicated weight of material is not within .200" of 4.000", then the estimate of compacted weight is revised in the light of the results from trial specimen and the process repeated.

CHART I

MATERIAL REQUIREMENTS FOR 4" DIAMETER SPECIMENS



The point of intersection of the lines representing, respectively, the estimated unit compacted weight and the moisture content of the material to be used indicates the weight (in grams) required for a compacted specimen 4" in diameter and 4" long.

INSTRUCTION SHEET
FOR
CONVERSION CHARTS FOR 4" x 4" SPECIMEN

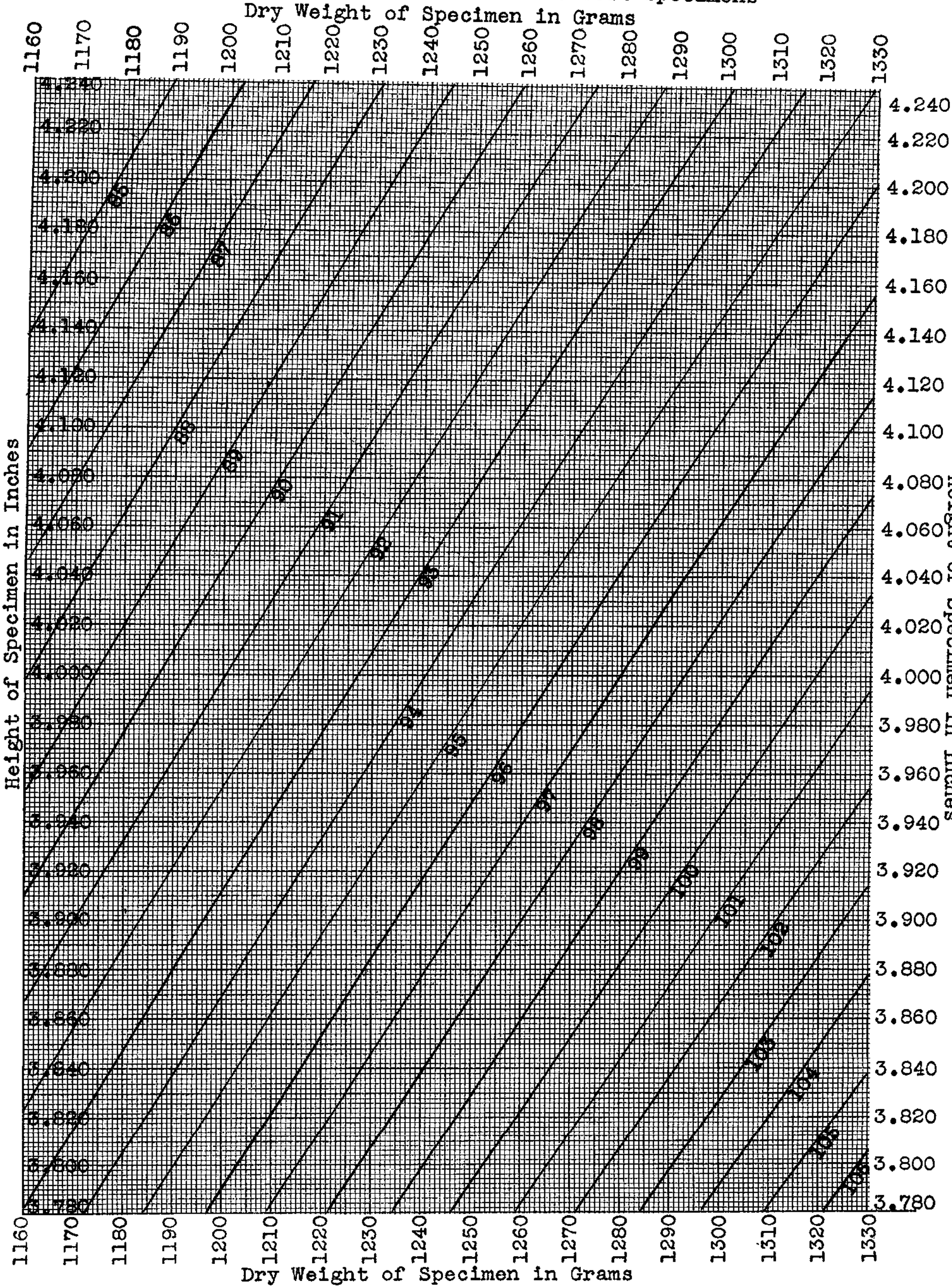
In order to eliminate the necessity for separate volume and weight calculations for each 4" x 4" specimen, a series of charts (A to E) have been prepared so that the compacted dry weight, expressed in pounds per cubic foot, can be read directly from the chart when the length and dry weight of the specimen are known. The charts cover lengths from 3.780" to 4.240" and unit compacted weights from 85 to 155 pounds per cubic foot.

The ordinates of the chart represent length of specimen in .001" increments and the abscissae represent the dry weights of specimens in grams.

After the specimen length has been measured by means of an Ames dial or a micrometer gauge and the dry weight calculated from the net wet weight and the moisture content, follow the lines indicating those respective values to their point of intersection. The inclined line immediately to the left of the point of intersection will show the whole number for the unit weight, expressed in pounds per cubic foot and the tenths of a pound may be estimated by interpolation of the point of intersection with respect to the adjacent inclined lines.

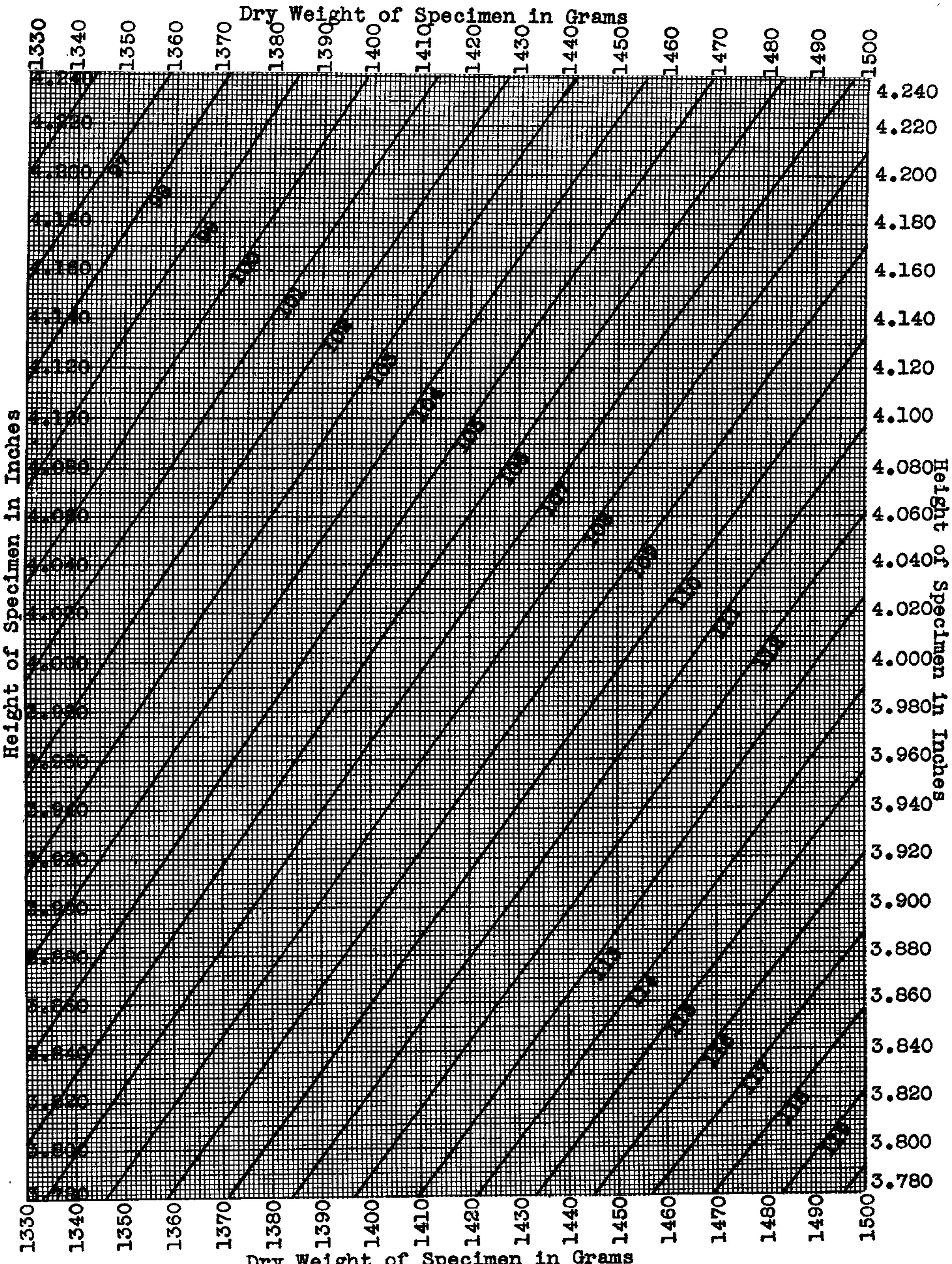
Conversion Chart - Sheet A

Weight per Cu. Ft. for 4" Diam. Test Specimens



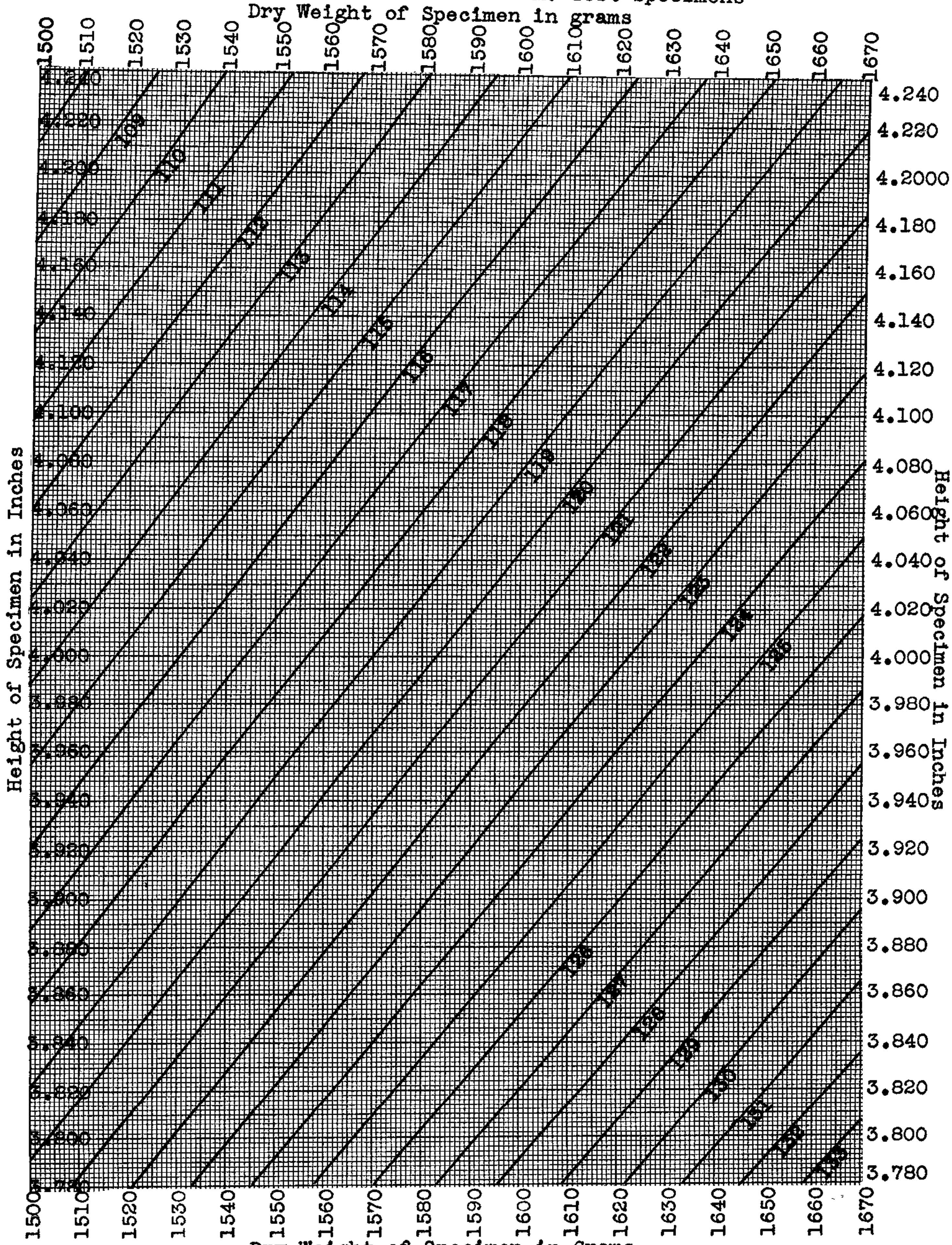
Oblique Lines Show Corresponding Weight in Lbs. per Cu. Ft.

Conversion Chart - Sheet B
Weight per Cu. Ft. for 4" Diam. Test Specimens



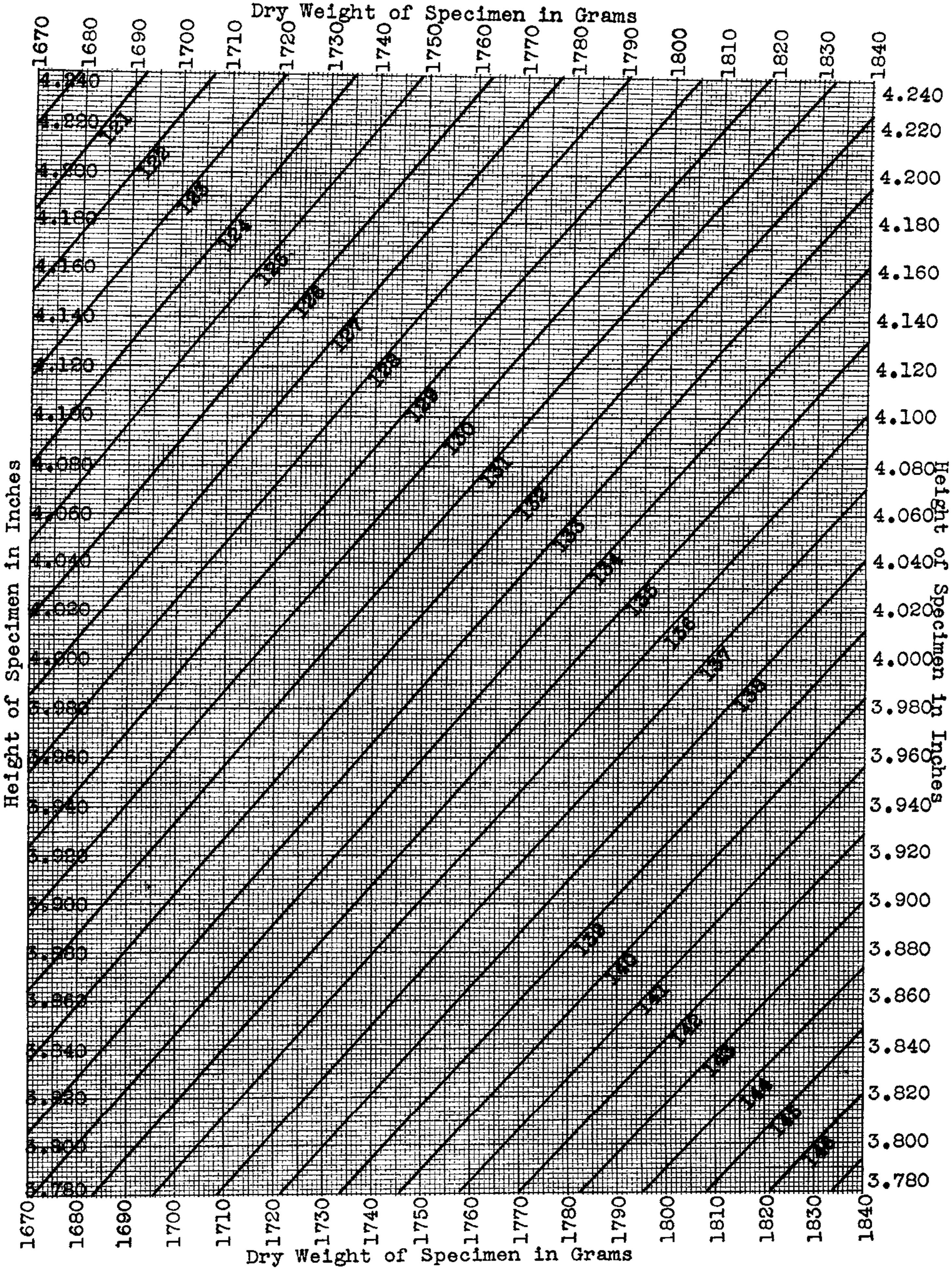
Oblique Lines Show Corresponding Weight in Lbs. per Cu. Ft.

Conversion Chart - Sheet C
Weight per Cu. Ft. for 4" Diam. Test Specimens



Oblique Lines Show Corresponding Weight in Lbs. per Cu. Ft.

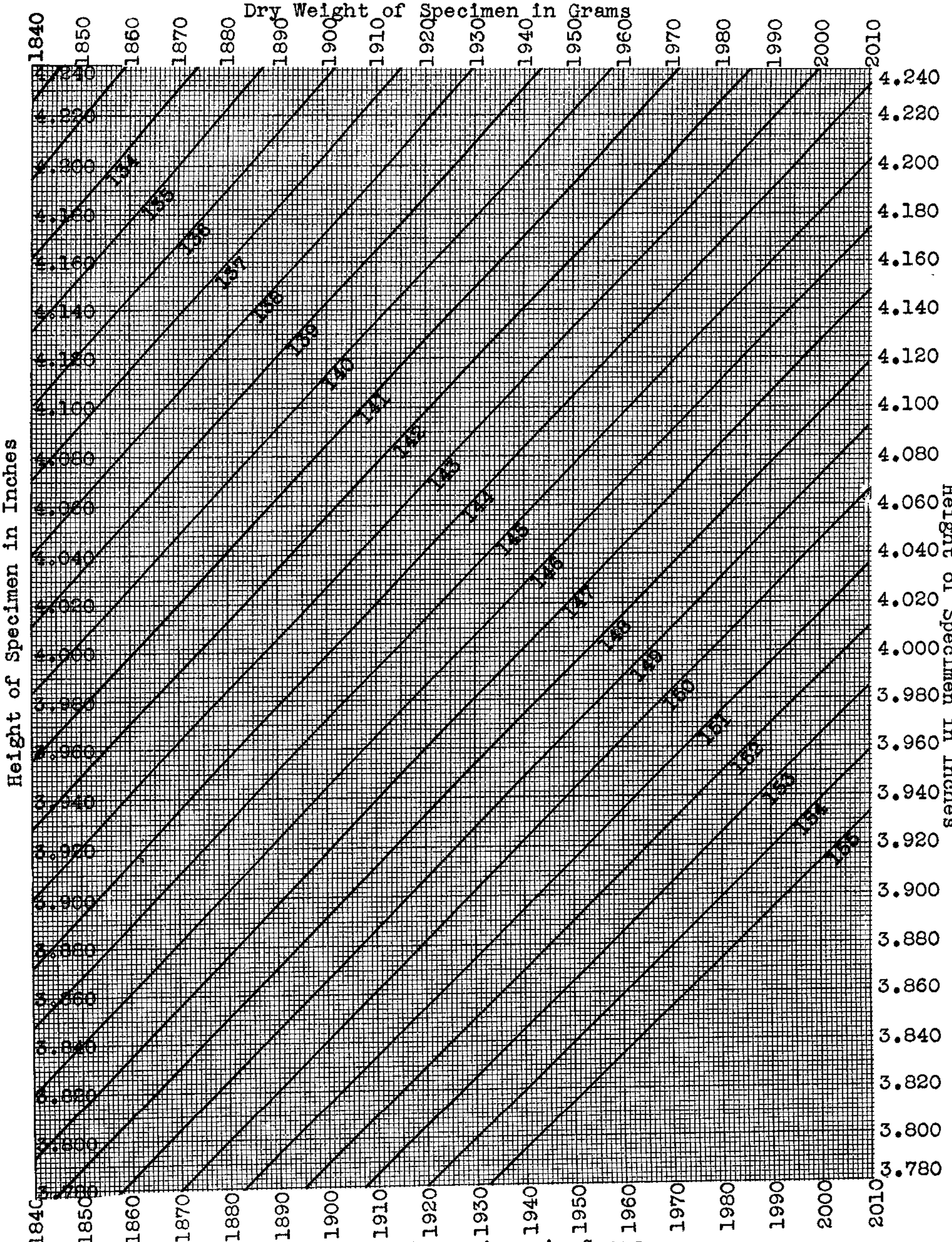
Weight per Cu. Ft. for 4" Diam. Test Specimens



Oblique Lines Show Corresponding Weight in Lbs. per Cu. Ft.

Weight per Cu. Ft. for 4" Diam. Test Specimens

Dry Weight of Specimen in Grams



Oblique Lines Show Corresponding Weight in Lbs. per Cu. Ft.

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS DIVISION OF HIGHWAYS
MATERIALS AND RESEARCH DEPARTMENT

CALCULATION CHART

FOR

RELATIVE HUMIDITY

March, 1942

RELATIVE HUMIDITY

CALCULATION CHART

The attached chart has been prepared for use in determining the approximate Relative Humidity of the atmosphere from the temperatures shown by an ordinary Wet-Dry Bulb Thermometer.

The curves for each 10% of Relative Humidity have been plotted from the data shown in Bulletin No. 235, published by the Weather Bureau of the U.S. Department of Agriculture, using the dry bulb temperatures as abscissa and the differences between the wet and the dry bulb temperatures as ordinates. All temperatures are shown in degrees Fahrenheit.

The values given in the Weather Bureau tables are based on temperature differences obtained by means of a sling psychrometer but are approximately correct for use with wet-dry bulb thermometers.

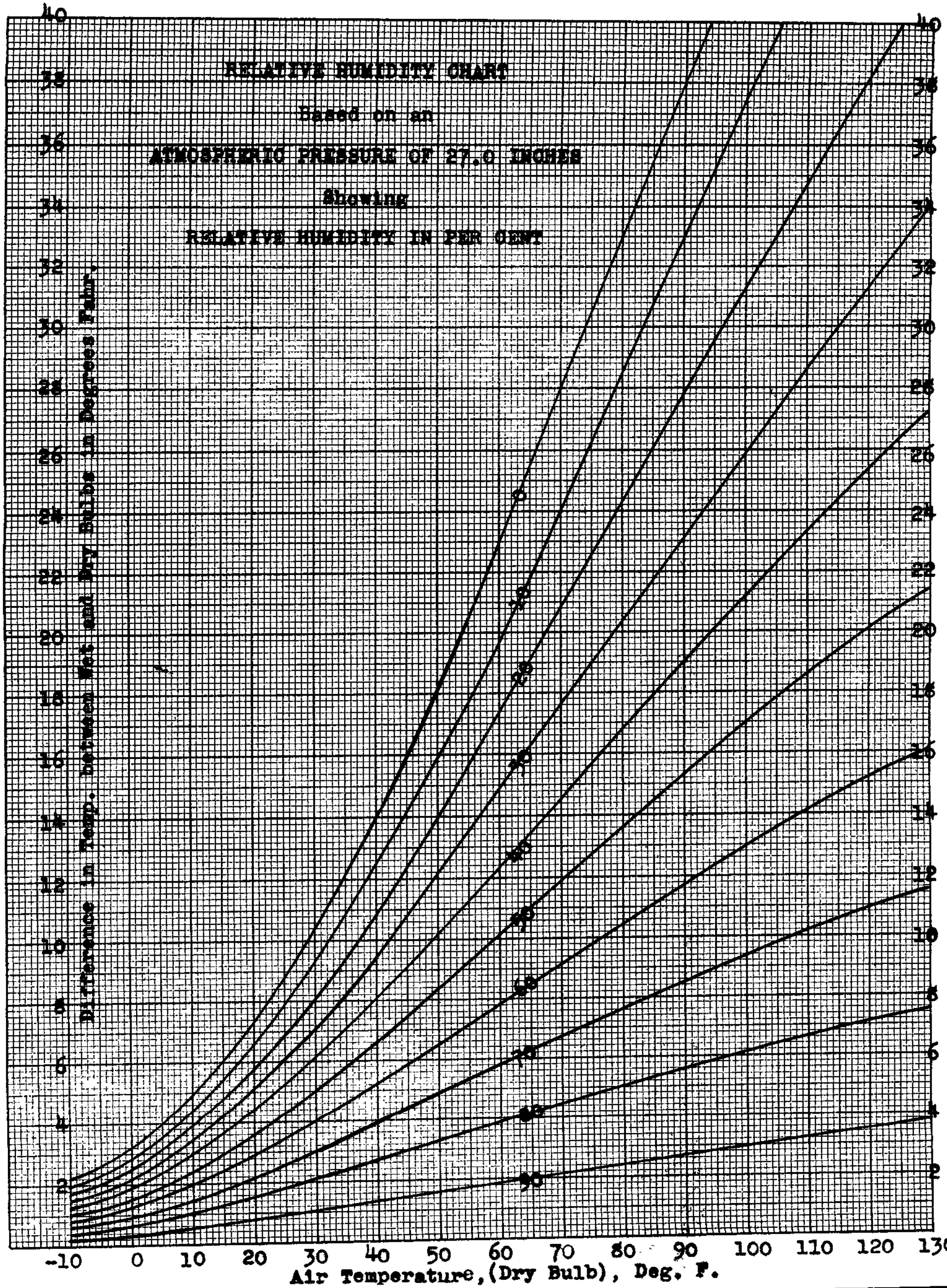
Inasmuch as a barometric pressure equivalent to 27.0 inches of mercury is about the mid-point of probable ranges in California and the relative humidity values shown in the table for a 27.0 inch pressure are approximately the average of all pressures, they have been used for the attached chart. The following table shows typical variations in humidity for given temperature differences with pressures other than 27.0 inches.

Except in extreme cases, the values obtained from the attached chart will be well within the degree of accuracy possible under ordinary conditions of observation with varying wind velocity, etc.

When making wet-dry bulb temperature observations, it should be borne in mind that the air should be flowing past the thermometers at an approximate velocity of 10 feet per second. If there is no wind, the proper effect may be obtained by fanning the thermometers for at least one minute before reading.

Relative Humidity for Various Temperatures and Pressures

Barom. Press. Inches Merc.	Difference Between Wet and Dry Bulb Temp. in Degrees Fahrenheit for Air Temperatures of 60°F.				80°F				100°F			
	5°	10°	15°	20°	5°	10°	15°	20°	5°	10°	15°	20°
30	73%	48%	26%	5%	79%	61%	44%	29%	83%	68%	54%	41%
29	73	49	27	6	79	61	44	29	83	68	54	42
27	74	50	29	9	80	62	45	31	83	68	55	43
25	74	52	31	12	80	62	47	32	83	69	55	43
23	75	53	33	15	80	63	48	34	84	69	56	44


RELATIVE HUMIDITY CHART
Based on an
ATMOSPHERIC PRESSURE OF 27.0 INCHES
Showing
RELATIVE HUMIDITY IN PER CENT
Difference in Temp. between Wet and Dry Bulbs in Degrees Fahr.
Air Temperature, (Dry Bulb), Deg. F.
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
0
10
20
30
40
50
60
70
80
90